Secret

Technology Trends Colloquium
Volume I—Rapporteur's Report

29 March - 1 April 1978
United States Naval Academy
Annapolis, Maryland

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A Department of Defense Research and Engineering-
Intelligence Community Publication

IA 100001-78
June 1978

25X1

Approved For Release 2004/09/03 : CIA-RDP86B00269R001400080001-7

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FOREWORD

This publication describes presentations and discussions at a colloquium conducted over a four-day period by a mix of technologists, systems designers and managers, intelligence analysts, and operational military. The colloquium was part of a joint Defense Research & Engineering - Intelligence Community technology forecast to determine what technology will be most significant for military weapon systems of the United States and the USSR for the rest of this century.

Technology forecasts are normally strongest in their statement of technical possibilities; and weakest in their relevance to political-economic-structural-demographic-human reactions and in their recognition of cross-impacts or substitutions. The mix of technical disciplines, future environment topics, and operational personnel was an intentional attempt to overcome such shortcomings.

The year 2000, or twenty years hence, may sound like the far future - a realm for wild thoughts. Unfortunately, many people concerned with defense planning are awed by a rigid ten-year acquisition cycle, and a ten- to thirty-year life cycle for deployed systems. The future appears to be known, and indeed no one would suggest that much of the equipment now or soon to be deployed will not still be used in the year 2000. In the past, however, major changes in equipments have evolved within a decade (e.g., the ICBM) to dramatically change war-fighting capability and significantly the perception of military strength. Quoting Peter Drucker, the proper rule is not, "whatever we do we'll do forever," but "whatever we do today will...be a candidate for abandonment within a fairly short period of years." The possibilities described in this publication should stimulate abandonment of the "more of the same" viewpoint.

The impetus for this colloquium came from Admiral Stansfield Turner. He engaged others in his idea and gave emphasis to the mix of technical and operational people. The colloquium benefited significantly from the co-sponsorship and active participation of Dr. William J. Perry, Under Secretary of Defense for Research & Engineering; as well as the guidance and active participation of the steering group composed of Dr. John Deutch, Director of Energy Research,

DOE; Dr. Stephen Lukasik, Senior Vice President of RAND Corporation; and Dr. Frank Press, Presidential Science Adviser. Ultimately, the fact of the colloquium and its content rests on all the participants who generously gave their knowledge and talents to the undertaking.

The text which follows is arranged by logical grouping of materials from the colloquium exchange. Every effort was made to give an accurate, though brief, account of main points. Any errors or misrepresentations contained in this report are unintentional and regretted. Individual papers prepared for and given at the colloquium are contained in the separate volume, and are commended to the reader as a more thorough treatment of the individual topics.

SUMMARY

The tasks laid before the colloquium were to identify where important technologies are going and where the leverage for military significance is in these technologies--for the US and/or for the USSR. This was not a comparative assessment of the United States and USSR. Technological possibilities were treated as neutral--that is, capable of exploitation by either nation, depending upon its institutions and purposes.

Forty technologies, systems, and conflict descriptions were selected beforehand for their likely significance. These formed the core of the materials presented--and thereby the future prospects.

These results do suggest priorities. For DOD activities their importance can be in the opportunities now seen to be significant, in the possibilities which are not prematurely foreclosed, and in the stimulation to think about a future different than a simple extension of today. Their importance for the intelligence community can be in the recognition of where US designs may depend upon threat definition or target signature variations, e.g., cruise missile defenses; in the identification of future technologies which need to be watched; in the understanding of the US (blue side) development, acquisition and operational strengths and problems; and in the recognition of research and development fields where information or solutions found by other nations could prove helpful in US developments.

Future Possibilities

- Flexibility gains, and thereby the capability for effective application of forces, appeared to the participants as the most significant military outcome from a number of these technologies. The explosion of data processing applications possible through large-scale integration, processing at the sensor, and cheapness is foremost in impact. Applications to weapons and to radar are of course expected of hardware designers. Application to evolve geographically and functionally distributed systems for target location, unit position location, air defense, and so on will provide for battlefield portrayal and the survivability of command and control. Most significantly, application to maintenance tasks, to multiple purpose maintenance tools, and to equipments capable of field changes in function will effect radical removal of logistical constraints on force operations.

A second source of flexibility gain is expected to be the wide use of insensitive or "wooden" explosives and propellants. These, used in smart and barrage weapons, eliminate the handling, storage and fabrication constraints now necessitated by fear of fire or accidental detonation. VTOL is a third source. VTOL aircraft equal in range-payload capability to today's fixed-wing aircraft can be available in the 1990s. A fourth source is the design of battlefield surveillance and weapons to explicitly gain the advantages of night and bad weather operations. The millimeter wave radar for these short-range applications is a likely consequence.

The last of the items identified with flexibility is the integration of small team operations and equipments in a manner analogous to the development of a tactical aircraft. These teams for both main force and special operations can thereby realize the protection, the target kill, and the fire/force direction potential from new weapons, sensors, computation and communications.

° A world-wide surveillance capability is expected through employment of space systems as well as over-the-horizon radars. Optical detection of subsonic cruise missiles, ships, and armor formations is expected from space utilizing large-space structures. However, the military significance from these achievements is unlikely to be realized unless the surveillance resources are organized and integrated with weapons allocation and handover capabilities; and provision is made for replacement of combat losses.

° The US and USSR are expected to become increasingly concerned about space access, and the consequent needs for active and passive defense against both physical and electronic attack. Active defense systems can include ground-based lasers for low altitude kill, both fly-by and positioned space-borne lasers, and space-borne lasers used for selective attack upon earth stations. Survivability for space assets is considered as achieveable as for anything else, naturally with the acceptance of payload and functional penalities.

° US anti-submarine surveillance is expected to continue dependence upon passive acoustics with up to 20dB gain in sensitivity. The USSR is likely to continue emphasis on short-range active acoustic and non-acoustic surveillance applicable to operations in enclaves and at barrier points.

° Mini-submarines, employing laminar flow surfaces and high-density propulsion, are expected for use in numbers as decoys, interceptors, or [redacted]. The use of submersible work systems is also expected to expand greatly, in part because the technology is being advanced rapidly by commercial interests in offshore exploration and deepsea bed exploitation. Their military significance will be in emplacement of sea floor supply caches. [redacted]

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° Naval surface vehicles capable of 50 to 70 knots are expected to serve as platforms for air surveillance, ASW, and movement of strike teams in crisis intervention. More significantly they are likely to fulfill new roles which remain to be defined by exercises and experimentation. The wing-in-ground (WIG) vehicle may complement or be an alternate in these roles, or even serve as a launch platform for cruise missiles or anti-air missiles.

° The life sciences are in a state of vigorous growth, yet the implications for national security are unclear. Genetic engineering will not change the combatant of this century who has already been born. Protective materials are expected to be more important to the nuclear-biological-chemical combatant than medical efforts.

° Silicon will remain the mainstay of electronics. Optical fiber and integrated optics will be commonplace. Laser treatment of materials will permit flaw-free parts, and rapid fabrication in the field.

° Accuracy improvements for strategic ballistic missiles are likely to be based on reference to global position satellites, not on inertial guidance improvements. Cruise missiles will be capable of CEPs of ten feet using

correlation guidance. Our cruise missiles face a formidable air defense and for penetration will depend upon low observable designs and not supersonic or hypersonic speeds.

Radical Change

- Radical change from the forces and weapons we know today was suggested by a few technologies. First would be the assimilation--not simply the existence of--sensors and processors by all forces. The obvious changes were mentioned, reprogrammable tools used in maintenance and logistical support, automatic detection and decoy of enemy illumination possessed by even infantry units, and fire-control solutions performed with a hand-held calculator in lieu of an installed system. Much more pervasive change in tactics, operations, organizations, and equipments is anticipated through the synergism of experimentation and field use.

- Second is the application of mega-power ground-based laser beams for propulsion. Multitude missile and space possibilities become feasible through the rapid repeatable launch and the cheapness of launch. Large structures become economical in space, anti-ballistic defenses could be placed in space, and mini satellites or decoys would become a space defense option.

- Third is the application of the particle beam as a space or ground based defensive weapon offering the possibility of superceding mechanical systems limited by inertia, thereby offering response times of milliseconds instead of seconds. A non-aimed beam might also be used as a weapon to produce a large radiation dose over a tactical area. Critical technical questions exist, but experimental work is underway in both the US and USSR on technologies applicable to a practical beam weapon.

- Fourth is the electromagnetic gun, a projectile propelled by a magnetic coil. By contrast with current guns, there would be no gun tube wear, flash, smoke, or similar signatures.

New Needs and New Approaches

Technologies were the focus, but beyond identifying what is technically possible is the question of how to make it possible. The disparity between the US and the USSR in fielding of new systems was very much the concern of the participants. The issue is not whether US technology can better fill a military need than can Soviet technology; but whether we can reverse our difficulties of recent years in choosing, designing, and producing systems which work, are assimilated, and are of reasonable cost. Effective technological exploitation was seen as crucial, but not yet in our favor, in the military competition with the USSR. Emphasis on operational experimentation and on the intrinsic quality of numbers were two of the more prominent suggestions for change in US practice.

Real concern was expressed about the attention given by the Soviets to continuous, including nuclear-biological-chemical, warfare in their doctrine, their equipments, and their training. US shortcomings in, even avoidance of, preparation for this type of combat makes the disbalance more critical. Obvious actions were discussed; but wider recognition of the breadth of the disbalance is a necessary first step.

Continuous warfare was one of the forms of future conflict discussed in the colloquium; force differences responsive to a concept of non-mutual assured destruction, to a world of nuclear proliferation, and to small unit type actions were others discussed. Inadequate as these were in covering the spectrum of future needs, they highlighted a major shortcoming in exploitation of our technological base. The lag in warfare concepts and strategy means our focus is upon bottom-up work--which comes from the traditional fields. Unrecognized is the lack of creative work in technologies which could be most important to long-term objectives; also unrecognized are areas of too much effort with low payoff. A combination of top-down and bottom-up selection was recommended.

Perhaps one of the more pervasive thoughts put forward in the colloquium was that of information war. Strategic intelligence is updated in bursts occurring in a matter of months or years. In a relatively stable regime of technical collection the capabilities of the collector tend to become known, and thus culpable to deception. A carefully designed

sequence of messages can cause reliance upon false input data and decision logic e.g. a designer is vulnerable to wrong or deceptive signature data. Furthermore, new vulnerabilities to tactical intelligence, and in actual engagements, result from the explosive use of information to optimize force and weapon allocation and control precision weapons. Information warfare is likely to need constant attention in the future, not the countermeasures afterthought approach so common in the past.

The colloquium's focus was upon technologies for weapon systems. Unintentionally, this appears to reflect the implicit assumption that machines and technology determine the outcome of wars. Those of this persuasion are impressed with the destructive power of modern weapons and view military personnel as rather unreliable machine-tenders whose function is to keep the equipment running. Fortunately, the operational participants present forcefully challenged this attitude much to the benefit of the colloquium's product.

KEYNOTE REMARKS

Dr. Perry gave the keynote charge to the colloquium. He first drew attention to two aspects of the organization: that it was a joint undertaking by two elements of the government, Defense and the Intelligence Community and, more significantly, that it represented a joining of forces between the scientific and national security communities. He noted that the latter communities had worked together in earlier years--with pride--and expressed his hope that this undertaking was a harkening of the better things to come.

He identified his two major themes for the colloquium: first, that of major military competition and, second, what science and technology has to do with that competition.

He gave examples of the seriousness of the military competition. The USSR spends 40 percent more on defense than the United States, but perhaps even more representative of the asymmetry is that the Soviets expend 30 percent of their GNP on consumer products while we spend 60 percent. They have deployed about twice as many pieces of tactical hardware and are producing at a rate 3 to 5 times ours. They have moved from marked inferiority in strategic systems to essential equivalence today and, as we see it, are driving for a position of superiority.

He noted that the competition is not only military, but is economic and has to do with the quality of life and the ability to maintain freedom of choice. In these other areas we are winning the competition. So our question is, what is necessary and sufficient to meet the military competition if we accept a 40-percent disadvantage in investment.

He cited President Brezhnev on the significance of science and technology in this competition. This he agreed with, noting that we have very fundamental advantages in this country in our industrial base and in our technological base. The issue is how to most effectively exploit this science and technology base--we must be extremely selective.

Dr. Perry said we have made choices with our R&D dollars in the past and that has led to the military capability we have today. Our technology serves as an equalizer to restore the quantitative disbalance between our forces and those of the USSR. In the next two decades we will again be depending on technology. The choice is even more critical, for while our resources compel us to be selective, the USSR is making a blanket approach.

The task he placed upon the colloquium was to identify where the technology is going and to identify where the leverage is in that technology and military systems.

TECHNOLOGICAL FUTURES

The colloquium was a 3-day snapshot of technology futures and possible military applications. The results are an input to a forecast, intended thereby to be a starting point for the harder task of resource allocation.

Dr. Davis in her summary provided a chronological listing of the technology presentations in terms of radical changes, incremental changes, and no anticipated changes. She noted the amazing and spontaneous consensus as to the constituents of US technological infrastructure for the next 20 or so years. These are: computer and software technology, distributed information/control networks, automation technology, materials technology, all weather sensor technology, and people.

She identified some technologies which need watching because too little attention has been directed to them, e.g., chemical/biological warfare technologies, maintenance technologies, etc. She placed emphasis on maintenance technology, noting that industry makes maintenance, repair, and keeping equipment operational a part of their business; and the DOD must give this greater attention.

Dr. Lukasik said the approach in the systems discussions had been to focus upon a set of systems that would reasonably span the future needs and relevant technologies--space systems, battlefield systems, etc. He related systems and technologies by a listing of technologies which had come up in the systems discussions. These include some overlaps with the lists of Dr. Davis, but also some differences. He emphasized that while these were generally high technology, the sense of the colloquium had been toward simplicity in design to achieve reliability and maintainability.

He drew attention at one topic from the systems discussion; namely, the one addressed by Dr. Rona entitled information systems (or information war). The future attainment of higher and higher levels of precision in surveillance, weapon use, and force allocation carries with it the greater vulnerability to deception prior to conflict or actual confusion and destruction during conflict by targeted actions against command-and-control links. This topic needs constant attention, not the afterthought customarily given countermeasures.

Many of these technologies offer new or enhanced military capabilities which will impact--and possibly cause major change in future forces. The extent to which USSR force changes are foreseen depends upon both our continued access to information of USSR developments and our applied knowledge of how the USSR exploits their technology. The extent to which such changes are foreseen, and actually occur, in US forces depends in part upon the stimulation generated by the materials of this colloquium.

Data Processors

The last decades saw the development and use of the programmable electronic computer, then the transistor, and now the present day silicon chip with its large-scale integrated (LSI) circuits. The cost per function has dropped dramatically so that inexpensive hand calculators and related microprocessors and minicomputers are now widely used commercially. Further integration is part of the future; but, more significantly, with low-cost processing many new tasks will be undertaken that today are uneconomical or not thought of. Large amounts of energy and force can be controlled in a manner similar to the way the brain directs the action of the muscles. This technology was thus seen by those at the colloquium as key, whether the application was toward separation of signals from clutter, guidance of missiles, distributed systems operations, or tools for maintenance and logistics operations in support of combat teams.

Dr. Dertouzos described the magnitude of expected hardware changes in memories and processors. By the late 1980s a million-bit chip memory will provide the equivalent of today's $100,000 computer for a few hundred dollars--purchasable for the homeowner or soldier. Similarly, by the late 1980s we will have available logic processors of 1 million to 5 million instructions per second (MIPS) at today's prices ($50 to $100). The significance by today's standards is that microprocessors will permeate instrumentation and control functions, individual use of computers will have a substantial qualitative impact on the individual's access to services and overall performance, and geographically distributed computer-communications systems will become the rule.

Radically new technologies may further increase memories in capacity and reduce costs. Single processor machines may be extended to 200 to 300 MIPS. However, these and even larger processing rates are more likely to be achieved by

multi-processors. He saw little advancement in input/output devices with continued reliance on the cathode ray tube, printer devices, and the keyboard. He noted that researchers are still struggling to construct programs that can comprehend spoken English. The significant exception will be that of the direct sensor computer interface.

The central processing units with large memories of today are a natural consequence of the considerably higher cost of logic switching or computation in contrast with that of memory storage. Now storing and logic costs are comparable, and we have the microprocessor. Mr. Joseph addressed microprocessors futures. He emphasized the rapidity of change. Until the late 1960s a new maxicomputer generation was developed about every six years, but since 1971 a new microprocessor generation has occurred every two years--small enough now and at sufficiently low cost to be integrated into common objects to give them intelligence. The integration will advance faster because interconnections are costly in power, maintenance, reliability, etc. Whereas the penalty for a signal now leaving the chip versus staying on the chip requires a hundred times more power, in a few years the number of circuits on a chip will increase by more than 10 times, and the power penalty will be a thousand to one--dictating designs where few signals leave the chip/wafer. Initially microprocessor hardware will be incorporated into computers and other machines, but he believes that, by 1980, entire systems will be integrated onto semiconductor wafers.

Dr. Dertouzos said these developments in processing hardware, the direct interface of sensors and actuators with processors, and the sizable improvement expected in bandwidth cost (glass fibers) bear directly on the instrumentation and control applications--and will bring about new levels of performance for individual equipment. New designs in such things as ships, airplanes, vehicles, buildings will come about by at least replacing heavy multiwire bundles with few glass fibers that link packet-oriented processing hardware.

Mr. Joseph added possibilities for dispersed operations that could be of significant security interest. A machine-like, nongeographically targetable, microminiaturized factory will produce end products. A mobile unit will have the versatility for complete maintenance of military equipments. Information transfers will substitute for the transfer of people and things, including where adaptation thereby of an appliance (tool) at a remote location performs a different function.

He gave examples of the lag in defense-deployed systems; that is, 10 years behind the defense systems state-of-the-art and 20 years behind the leading edge of the commercial exploitation. The obvious need is for military-related systems to upgrade at a faster pace to keep up with commercially available systems. He foresees the ability to imbed micro-processor-like logic at the interface of complex systems, thereby allowing such systems to be used by the uninitiated and untrained, to aid immeasurably in closing the gap.

Similarly, he saw the significance of the microprocessor future for the military as offering the elimination of technological obsolescence for defense systems. These can be designed for continued/constant piecemeal updating, which will permit systems, vehicles, missiles, and so on to be readily adapted to a changed threat or a different physical environment. This means saving in major system buys, savings of energy, and savings of materials.

Technology can be the driver for individual equipments. Dr. Dertouzos noted by contrast that while the technology will make distributed systems possible, the principal force behind distributed systems is simply the natural geographical distribution of the collectors and users. The extent to which these systems become widespread depends critically upon the evolution of languages and operating systems designs. The most dominant application is likely to be clerical and logistic support automation, that is, the mail and message systems, text editing and preparation, maintenance of records, and clerical functions. Other applications include military intelligence, where inputs can be linked to an informational structure and retrieved inferentially and associatively rather than by key words; commands and assessment of forces issued over widespread formations; and stationery and mobile radars netted.

Dr. Hart joined in to carry the possibilities offered by greatly expanded memories and processor capabilities to even more difficult tasks. He contrasted conventional computer programs with the work in Artificial Intelligence (AI). Conventional programs ordinarily perform an inflexible operation upon a rigid set of inputs. Clearly, this speed and processing power ought to be more responsive to variability in inputs and unanticipated queries. AI achieves this in part by incorporation within the system of a substantial body of knowledge about the problem. For example, a system for analyzing aerial photographs can contain more than the visual appearance of trucks; it can contain relations

between trucks and roads, rivers, and bridges and relations between buildings and roads and so forth. The AI program can thereby interpret and analyze inputs such as photographic imagery, generate and execute a routine to answer the query, and measure the output against a desired goal.

Within the past few years, AI systems have demonstrated experimentally that they can provide consultation services to physicians on problems of medical diagnosis; determine the structure of large organic molecules from their mass spectra; analyze aerial imagery to monitor ship movements; deduce, from the content of data bases, the answers to questions posed in ordinary ungrammatical English; interpret continuous human speech about restricted domains of discourse; and control robotic vehicles and manipulators on the basis of video and other sensory input. He cited possible future military applications: the direction of multisensors on EW surveillance platform by verification of anticipated emitter presence or recognition of gaps in the current electronic order of battle; the monitoring of a stream of logistics data to determine critical exceptions to the execution of a plan; the interrogation, in ordinary English, of a set of distributed computerized data bases to form an assessment of assets or to test the feasibility of a contingency plan.

Dr. Hart saw the growth of AI to depend upon the acquisition, representation and use of knowledge. The discussion suggested an example. The enormous gain in oceans knowledge projected by Dr. Wunsch, as exploited incrementally by AI programs could accelerate knowledge of the oceans and also be applied to ocean surveillance, surface vehicle weather avoidance, and sensor designs. He saw the exploitation of multiprocessors as a further source of AI growth. Designs involving hundreds of general purpose processors or millions of simple logic units can provide the large amounts of computation AI systems typically require. Dr. Dertouzos noted that multiprocessor systems will be needed to achieve processing rates of 1,000 MIPS and up for tasks like weather forecasting, partial differential equation operations, and speech processing. Unfortunately little development of multiprocessor organization is under way.

Discussion brought out an issue concerning the growth of microprocessor systems, distributed systems and multiprocessor systems: namely, the absence of software, the difficulties and high cost of programming, and the availability of programmers. Dr. Dertouzos suggested the solutions

probably will utilize natural-language filters that precede other programs, and larger amounts of structured knowledge with relatively few processing rules. Mr. Joseph carried this point about programming cost a step further suggesting the future approach would be counterintuitive. Today the design of future systems must be software compatible with old systems, since it costs about $50 to develop a single line of new code. But we overlook the life cycle cost to maintain that line, which involves thousands of dollars because the past programs are in low-level languages. In the future we should throw away the old program and redo in a higher level language--replaceable dedicated computers on a chip will further this direction by casting software into hardware.

This means it will be cheaper to buy a new chip in order to replace the program. There were questions whether the military could constitute a significant enough market to make this approach economical. Mr. Joseph stated his belief that the costs will indeed be cheap enough to meet the special purpose needs of the military.

The gap between technology and field operations was echoed by many. General Dickinson noted the large computer had not been compatible with Army operations, but the possibilities for distributed operations and the robustness of the integrated circuit processors appeared to fit well with Army operations. Mr. Chapman cited a 1977 ASW exercise wherein an individual on the bridge of the destroyer was able to compute the fire control solutions with his HP calculator more rapidly than the installed system. Yet there is no provision in current procedures to experiment or adapt those gains. This example, and those furnished by others, amplified Mr. Joseph's point that the future can only be realized for the military by anticipatory design makes explicit provision for update in the field.

Computers and data processing naturally brought the discussion to command and control as a topic. The new technology facilitates local processing. Dr. Rona emphasized how the analogous biological functions work well independently--decoupled. Decentralization offers the benefit of local tasks well done and reduces the vulnerability to countermeasures by the enemy. Dr. Davis also emphasized in her summary remarks the group's view of strong need for decentralizations.

Surveillance

The sense of the colloquium was that surveillance technologies are indeed impressive. Knowledge of the location and movement of enemy and friendly units is important to warning, to allocation of forces, and to eventual engagement. There were important reservations over the military gain from these technologies. Principal reservations were about the integration of the information, about the adequacy of handover to units and weapons for engagement of targets, and about countertactics such as those presented by Dr. Rona as information war. However, neither time nor adequate specifics permitted more than an expression of these reservations.

Radar is expected to remain the principal surveillance sensor. Dr. Skolnik identified recent major United States accomplishments in radar as centered around the processing of data and extraction of information. He cited improvements in MTI and pulse doppler radar, AEW and AWACS radars, synthetic aperture radar, high-frequency over-the-horizon radar, pulse compression, automatic detection and tracking (ADT), ECCM, and remote sensing of the environment. The expected, even more revolutionary, growth of processing capabilities within the United States means future United States radar capabilities will likely develop from these strengths. Significant examples include: the classification of noncooperative air targets as a complement to or substitute for IFF, expanded synthetic aperture radar (SAR) imaging of terrain and targets in direct support of military operations; automatic integration of outputs from multiple radars as well as the integration of radar data with that from other sensors; adaptive control of antenna pattern, MTI and ECCM (sidelobe canceler); highly reliable radar systems; and further refinement of ADT to overcome the display/operator weak interface.

Mr. Longuemare added to the list of radar advancements likely to evolve from processing capabilities with emphasis on airborne applications. He cited solid-state power generation, signal processing, and system design as the driving forces. He estimated a 100-fold increase in solid state radio frequency power generation by combining output to function as a direct replacement to conventional tube units. This output will be coupled with electronic scanning, adaptive beam-forming antennas. In signal processing, the received signal will be digitally encoded directly at microwave frequency and stored in bulk memory for processing in both

beam space as well as time-frequency space. By system design, multiband transmitters will permit coordinated use of the same hardware for jamming, radar functions, and secure data link functions. In sum, he expects generalized programmable hardware which covers multiple bands to be controlled in real time so as to perform both interleaved and simultaneous functions.

He also emphasized radar developments for target classification and identification. Classification of a moving target such as an aircraft, missile, moving or hovering helicopter, treaded ground vehicle, or wheeled ground vehicle will be possible at 90 percent confidence within 10 years. Identification is more demanding; but with high-range resolution radar, passive ELINT, and jet engine modulation, he saw probabilities of 85 percent for correct fighter identification at ranges of 150 to 200 nautical miles, and probabilities of 99 percent for correct identification by interceptor aircraft at ranges of 10 to 20 nautical miles. Realization of these could answer a major long-standing problem of air defense. Many were skeptical of its feasibility for application in the dense NATO area. Further caution was given about problems that may occur outside the NATO theater because of wide use of US aircraft sold through military sales programs.

He predicted bi-static radar use; that is where one remote transmitter illuminates an area and multiple receiver systems function simultaneously both for surveillance and for passive operation of strike systems. Dr. Skolnik doubled the application. He noted that when the bistatic radar is considered objectively with a monostatic system to perform the same function, the bistatic radar is found wanting. Mr. Tachmindji echoed the same negative view in respect to bistatic (or multistatic) radar application to air defense.

Dr. Skolnik drew attention to the need for antenna developments. Current and future radars are expected to employ mechanically rotating antennas. These include lighter weight antennas and mounts, improved stabilization for shipboard and airborne radars, faster scan rates, cheaper multiple-beam antennas, transportable and easily erectable antennas, and designs less vulnerable to battle damage. He noted developments of mirror-scanned antennas that may provide a wide frequency range from a single antenna for rapidly scanning surveillance and track-while-scan with data rates competitive with phased array radars. He said the latter has yet to prove to be a cost-effective solution for

most radars. He identified the HF OTH radar as offering the most significant advance in military capabilities. Applications cited were over-the-ocean detection of aircraft, missiles, ships, targeting of offensive missiles and sea state measurement. He saw the future of OTH to be less one of technology than of funds and established need.

By contrast, he credited the Soviets with demonstrated lead in deployed radars such as space-borne radar, shipboard radar, ABM radar, and the HF OTH radar. Along with the obvious strengths from such operational experience, he emphasized their strengths to be in high-power transmitter tubes, antenna design, and multiple-frequency applications; and the mature and thriving radar industry developed through their heavy stress on defensive systems. Emphasis on high power, selection of frequencies, good design work, special circuits, deployment practices, and operator training reflect keen awareness of the need for ECCM in current Soviet radars and likely future radar systems. He saw the US lag in these areas as not only a disadvantage for our own design, but adding to the difficulty of forecasting where the Soviets are heading. Some examples such as pulse-repetition-period modulations on a large number of radars, the function of the Top Steer and other radars on the Kiev, the nature of Head Lights and its role on "large ASW" ships, the limited scan of some ABM-related radars, the role of large phased-array radars, and the oversized radars on Bear D aircraft and Hormone helicopter escape our understanding of the radar's parameters or method of operation.

Mr. Longuemare and Dr. Skolnik emphasized expected improvements in radar reliability and maintainability. Mr. Longuemare cited 100 hours as the current mean time between failure (MTBF) for current fire-control radars with 1000 hours technically possible but economically inappropriate. He predicted systems of the 1990s to operate for years without functional failure. Emphasis on such achievements was welcomed by several military participants who characterized current equipments as non-operable and said most manpower is now consumed in attempting to keep it operable with subsequent loss in readiness and training. Skepticism prevailed. The recent figures provided in writings elsewhere by the Honorable Norm Augustine (past Under Secretary of the Army) were cited to the effect that while over the past 20 years the specifications for electronics equipment have increased exponentially, the actual reliability has remained at a constant 10 hours MTBF.

Mr. Justice presented developments in optics, not as a competitor to radar, but with emphasis toward their eventual use as complements. He identified the principal technology

developments under way in electro-optical sensors as large-scale mosaic focal planes, programmable spectral filters, integrated on-board signal processing, high-capacity high-efficiency cryogenic coolers, and adaptive optics. He saw the principal application of these technologies to be in satellite-based surveillance.

Current systems, characterized by the Defense Support Program (DSP), are line scanners designed to see large ICBM and SLBM boosters burning against the earth background. Space-looking sensors have the capability of detecting most satellites using their thermal emission viewed against cold space. By contrast, these new technologies in 10 years can provide for ICBM/SLBM booster detection and tracking with sufficient accuracy to determine launch point within one kilometer, tracking of MIRV bus burns, detection of high-power aircraft take-off, detection of aircraft in supersonic flight, detection of tactical munitions such as artillery, tank firings, and small rocket and tactical missile launches. Within 20 years, the increase in sensitivity will allow detection of subsonic cruise missiles, ships, and armor formations.

He described infrared sensors as having been limited in performance by their scanning mode operation and the limited number of detectors that could be employed. The technologies here will employ millions of detectors and maximum use of large-scale integrated processing to abandon scanning mode operation in favor of staring or step/staring modes. The payoff is an increase in sensitivity by several orders of magnitude. A nontrivial adjunct to the sensor and processing technologies, if these large structures are to be used, is the ability to measure and control disturbance in the optical systems so that the essentially nonrigid optical elements can be erected and maintained in individual quality and alignment (adaptive optics and adaptive structures).

Mr. Justice placed his confidence in these projections upon the broad program of technology investment by the Defense Advanced Research Projects Agency in each of the fields he described. The discussion brought out his concerns as well as those of others that the increase in sensitivity of several orders or magnitude means handling high clutter. Emissivity and temperature variations in the land and sea backgrounds and from cloud to land and sea interfaces produce differences that can far exceed the target signal strength. Staring mode operation is an inherent help in removing fixed pattern spacial structure; yet modulation may result from

shifting weather patterns, sensor line-of-sight motion, inherent temporal structure or scintillation may also exist in the natural background. Significant signal processing will be required to extract targets, and to date there has been insufficient progress in measurement and understanding the exact nature of fine-scale background clutter. Signal processing knowledge lags hardware technologies.

Dr. Hyde brought emphasis to ocean surveillance applications. He said the US does not expect to regain a clear naval advantage through fleet platform expansion in the next 25 years. In fact, an increasing numerical gap against an increasingly sophisticated naval adversary is expected. We must be able to discriminate threat targets from nonthreats. Standoff capability of Soviet submarine-launched missiles is expected to be increased beyond 250 to 400 nautical miles and in effectiveness with improved Soviet ocean surveillance. The Backfire Bomber will permit very rapid delivery of long-range antiship missiles. This overall picture provides a backdrop against which to judge new technologies in ocean surveillance.

The remarks here pertain to surface ocean surveillance, ASW is treated in the section entitled naval warfare. Dr. Hyde said our current capability for surface surveillance is provided by multiple passive SIGINT systems. The [redacted] Shore-based HF/DF, along with sea-based, will be upgraded to improve net operation and is expected to remain a major contributor to location identification and tracking of peacetime commercial shipping as well as Soviet ship and aircraft combatants in peacetime. These, aided by rapid data correlation and dissemination, will be the basis for viable over-the-horizon targeting in the 1980s.

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Technology can further these capabilities, recognizing that ocean surveillance is multitechnology, multimission and geographically dispersed with individual vulnerabilities to enemy action. Bistatic intercept processing of emissions utilizing space-based, large aperture antennas offers the advantage of better propagation than intercepted emissions. Intercept of unintentional radiation from threat radars is suitable for target identification within local areas and may be used over much wider areas by application of such space-borne antennas. Standoff radar imaging through use of

inverse synthetic aperture techniques can create a doppler-range map which approximates the optical image and thereby provides classification of selected surface targets with the space-borne radars. Space-based mosaic IR may provide for over-ocean detection of radiant objects such as Backfire Bombers, naval cruise missiles and surface combatants. If these space-borne concepts prove unfeasible then high-endurance, high-altitude aircraft offer an alternative platform.

Land Combat

This topic perhaps received more attention than any other throughout the colloquium. European theater conflict was obviously the main interest, although the NATO flank areas as well as operations in other geographical areas were introduced from time to time. Aircraft, their survivability, and RPVs were discussed. Ground vehicles and helicopters were not discussed. Two large "systems" possibilities were discussed, that of ground target location and that of air defense. New explosives and propellants for ground, air and naval use; and guidance for ground-launched missiles were discussed. Lastly, the soldier's combat environment and the significant potential for overall enhancement of combat teams were major topics of discussion.

Mr. Hedrick described the possibilities for achieving significant aerodynamic improvements for tactical aircraft in subsonic, transonic, and supersonic regimes. Along with the natural opportunities for smaller vehicles, less fuel and lower cost, this will permit introduction of technology that reduces visibility to enemy sensors without performance degradation, carriage of weapons without performance degradation, or high sustained maneuverability at all Mach numbers.

Two significant items were cited. First, the most dramatic improvement expected over current tactical aircraft is in the application of combined aerodynamics/propulsion technology to achieve efficient supersonic non-afterburning cruise for penetration. Combined with the above, the continued survivability and utility of the tactical aircraft is attainable--but with increasing cost.

Second, vertical takeoff (VTO) vehicles, while continuing to have a weight and cost penalty with respect to conventional takeoff (CTO) contemporaries will after 1990 have a better useful load ratio than current CTO tactical vehicles. Thus

with the expected advances in weapons and avionics VTO flexibility and survivability will be attainable without real loss in firepower.

Dr. Hicks cited the technology now available for remotely-manned vehicles, or more specifically for remotely piloted vehicles (RPVs). He pointed out that the available technology was well beyond that utilized. Furthermore, extrapolation of capabilities from microprocessor and sensors that exploit LSI electronics, from spread-spectrum data links and compression techniques to resist jamming, and from low-cost mass producible vehicle structures and propulsion systems that need not be man-rated all portend the age of the tactical RPV to be at hand. He described potential military uses as target acquisition and designation, defense suppression including harassment, decoys, and active countermeasures in environments characterized by high attrition. Advantages attributed to RPVs are those of lower cost and no human exposure for hazardous or politically sensitive missions. Yet, there are no clear concepts for RPV use; there are a multitude of questions about tradeoffs with manned systems, about reliability, and about vulnerability to jamming and deception; the image of cumbersome field support also remains. These block the development of current or future RPV systems. The situation was characterized as technology looking for a use.

The discussion brought out specific technological achievements that could dispel these doubts. Noted was the capability to accomplish electro-optical detection and processing within a single chip, the effective operation of real-time imaging using kilohertz instead of megahertz bandwidths, the reduction in long-endurance vehicle size (and thereby in field support) to weights of less than 45 kilograms and landing capture by net.

General Gray noted that while the applications are exciting, the setting up, support, and camouflage of burdensome ground equipment remains a drawback even when it involves only three men and a truck. The direction must be toward true mini-RPVs, that is to say man-portable.

The sense of the discussion was that although individual efforts are under way, the case for other than few-of-a-kind use remains unsold. It seemed highly unlikely to most that the RPV will be exploited for tactical warfare without the combination of convincing operational experimentation and senior-level commitment.

Mr. Greene described the employment of distributed systems for position location, navigation and guidance, and information processing as the significant future for the battlefield. Distributed sensor inputs such as time-difference-of-arrival (TDOA) for the location of electronic emissions, wide-area surveillance and tracking MTI radars, synthetic aperture side-looking airborne radars (SLAR), reconnaissance aircraft and satellites, plus special purpose ground sensors provide multiple signature data. When these inputs are tagged with time and location, then large computer capacity on a chip, coupled with distributed communication networks and advanced displays, can correlate and display these as time-ordered pictures of a dynamic battlefield for air and ground users. This battlefield portrayal can be used for force allocation and battle planning, and for assignment of units.

Significantly, control of ground- and air-delivered weapons will also be possible through association with a Distance Measuring Equipment (DME) grid. Area weapons, or when appropriately matched terminally guided weapons, can be employed against any target, emitting or nonemitting, which can be located in the DME grid--by photography, by reference to DME ground transponders, by reconnaissance aircraft or RPV equipped with DME transponders, or by transforming MTI or SLAR radar fixes into DME coordinates. No forward observer will be required.

Mr. Greene noted the technology of sensors, chip computers, and secure-survivable communications provides this opportunity. The exploitation can only be achieved through evolutionary exercise and test with fielded operational units as the acceptance of the concepts and the evolution of the tactics are the essential difficulties to overcome.

Mr. Tachmindji identified the future air defense threat to include low radar cross section missiles, RPVs and decoys, ECM, physical destruction, and the full complement of tactical aircraft and helicopters. Radar will remain the principal air defense sensor for warning, surveillance and tracking.

Techniques to counter ECM will be developed and employed which will permit clutter-free tracks or noise strobes to be passed. The penalty from ECM is of course significant decrease in radar range. Reduction in the radar cross section (20 to 30-dB head-on for cruise missiles) also means a significant decrease in radar range and the possible

dependence on beam and tail aspect returns. Overcoming the loss of range and response time means increased reliance upon shorter range missiles and guns to protect the ground targets and thus the technology that can make these affordable.

Technology also affords the possibility of netting the air defense system (sensors and weapon systems) as a further aid to overcoming the loss of range. Netting would involve ground-based radars and airborne radars with them (AWACS, F-15, F-16) in order to fill in for ground assets as they are destroyed. The challenge will be to make fundamental changes across national and service lines.

He described the problem faced in avoiding attrition of our own aircraft while performing air defense in the Central European Theater. A hypothetical aircraft flight from Ramstein to the Rhine sector (approximately 200 nautical miles) may pass over territory covered by six different National structures, 10 different service structures, 40 SAM batteries, more than 400 surveillance elements and more than 800 short-range air defense systems (SHORADS). Each of these systems would essentially be identifying the aircraft autonomously. In another case, SHAPE flew an aircraft over the British sector at an altitude of 15,000 feet; and at one instant in time the aircraft was being interrogated by more than 550 autonomous systems.

Except for procedural solutions, there is no present, technically acceptable solution to the identification-friend-or-foe (IFF) problem in the European Theater. A secure communication system similar to JTIDS connecting all aircraft and helicopters with a netted air defense, able to pass IFF, would allow a near complete air surveillance picture to be available at local sites. Discussants remained genuinely skeptical over the possibilities for theater-wide solution of the IFF problem.

Dr. Kury and Mr. Popolato presented the possibilities for development beyond Triaminotrinitrobenzene (TATB) to highly insensitive (wooden) explosives with energy equal to or better than our current explosives. These are potential fill for both smart weapons and for barrage weapons (shells and bombs) with enormous operational gain, billions in cost savings, and wide use of industrial facilities. Their characteristics are the unlikelihood of accidental detonation and a significantly longer storage life than current fill.

Production and storage facilities would be less expensive, transportation by train or ship would be safe, storage in large quantities at nonremote sites (such as adjacent to the aircraft on shipboard without fear of a Forrestal or Enterprise accident). These explosives when coupled with related developments in detonators, that will make them safe and will focus warhead energy, indicate enormous gains can be achieved.

The explosives are important, but an equally vulnerable element is the propellant charge. Significantly, Dr. Fair identified the possibilities for spinoff development of low-vulnerability chemical propellants. Analogous gains in operational use and cost savings to those for explosives can be expected and, coupled with thermal protective materials for the gun bore, will offer both safe handling and greater range.

The point was made that the segment of the US technical community devoted to explosives is too small and too fragmented to achieve these ends. A further obstacle is the weapon designer's prevalent attitude of selecting the appropriate explosive from the existing arsenal instead of including explosive development into an integrated approach toward life-cycle cost effectiveness. The significant gains from insensitive explosives was seen as the possible catalyst which may reenergize the community activity.

Dr. McDaniel began his remarks by suggesting that in the future our ground forces must not shun limited visibility conditions but rather use these conditions to advantage to achieve a series of intense surprise engagements with tanks and enemy force units. Likely conditions are darkness, fog, rain, and/or obscuration by dust and manmade smoke. This means new <u>battlefield missiles</u>.

He expects the millimeter-wave radar, with its unique quasiradar/optical propagation characteristics, to be widely used for short-range command guidance. Optical, infrared, and laser guidance is unsatisfactory under these conditions. Millimeter-wave gains are radar-type performance where visibility is bad, small volume similar to optical or laser devices, and narrower beams for imaging and less interference. Millimeter applications (70 to 300 GHz) will include target-acquisition-and-identification radar, beam-rider missile guidance, semiactive homing guidance, and terminal guided submissiles. Mr. Longuemare added additional emphasis to this coming use of millimeter waves.

Dr. McDaniel then noted optical developments likely to have wide application to battlefield systems. Mosaic focal plane arrays employing IR-charged coupled device detectors, integrated with processing, all on the same chip will make possible cheap, nonmechanical scanning, software-reprogrammable correlation trackers. Development then of alignment techniques for small-field-of-view IR image to FLIR image correlation under varying conditions of terrain and weather will complete the possibilities for IR passive acquisition and homing fire-and-forget capabilities. Separately, the fiber optics data link offers the possibility of over-the-hill missile systems using a secure optical data link to transmit video data from an in-flight imaging sensor to the launcher and to transmit commands back to the missile.

Dr. McDaniel left no doubt that direct-fire weapons were a must, but stressed the need to husband these by new developments for attack upon second and third echelon units. The thrust of these arguments were toward technologies which would provide fire-and-target delivery of submunitions at 10 to 100 km ranges. IR, and millimeter, and microwave guidance were all identified as possibilities for terminally guided submunitions attack on ground surveillance, tanks, artillery, and vehicles. Delivery by tactical aircraft, tactical cruise missiles, helicopters, artillery, and general purpose rockets were all suggested. He saw the pacing technology as that of location and identification of enemy targets, and RPVs as the likely platform for these functional tasks.

Mr. Justice drew attention to the theater application for mosaic focal plane arrays as a natural adjunct to radars. He suggested beyond space surveillance sensors and their use in guidance already noted that other theater applications are IR AWACS, air-defense penetration, interceptor search and track, perimeter defense, hardsite defense and fleet defense.

Discussion of land combat technologies and battle conditions reoccurred throughout the colloquium. Precision guided missiles (PGM) in use by ground and air units were presumed throughout the next two decades. Survivability of our tactical aircraft was a major topic with clear concern expressed for development of antiradar missiles to strike enemy defenses and concern expressed for the vulnerability of our air bases and the protection of the aircraft thereon. Mr. Greene suggested additional operational and maintenance crews were needed for our aircraft so that continuous operations could be maintained. He argued that for high-investment

items such as aircraft and tanks, crew shortages not equipment shortages were likely to be the constraining factor. The ever present concern over the adequacy of NATO air defenses was the subject of much discussion, but no concensus; except to affirm that short-range systems will be key.

The importance of continuous warfare and nuclear, biological and chemical (NBC) warfare was recognized as pervasive if real preparations were undertaken. Some technologies for night vision, for forward repair, and for protection were cited but no participant suggested that the magnitude of change was even understood.

The infyonics concept for integral development of small units, their equipment, and their support excited most participants as an approach likely to maximize the exploitation of new technology and thereby gain real leverage for US land forces. Other than the new technologies two ideas were central. First, that the small unit be developed in an analogous fashion as that of a tactical aircraft instead of the current practice of appending gadgets onto men in the unit. Second, that the mission for these units be "engage and defeat," not "close with and destroy the enemy by fire and maneuver" as currently written. Defeat-not-destroy better recognizes the operational concepts within which a unit can best employ the new technologies--and the support available to it--while also recognizing "close with and destroy" is an unlikely task for a small unit facing a tank or armed helicopter. General Gray cited the Marine Sting Ray concept, and the ARPA Small Independent Action Force (SIAF) as past examples of such emphases--but without the advantages of the sensor, weapons, and processing technologies soon to be available. Several emphasized that however appropriate the development of small units was for low-level conflict, it was equally essential to large-force operations of the future.

General Dickinson along with General Gray and others cited what they saw as the tremendous potential from the new technologies for logistics. Force projection and sustained operations are dragged down or made possible by logistic support--now tied up by depots and long logistic trains. New technologies which can reduce this train are: weapons which will hit what they are aimed at, the miniaturization of equipment, the processing available to anticipate and speed up response, field reprogrammable tools and equipments, and the insensitive explosives. Dr. Bement's projection of

battlefield "cloning" of repair parts for existing or captured equipments added to the excitement for vast improvement in logistics and maintenance. The radical change in maintenance and logistics was seen as most significant because of the freedom thereby created for combat unit operations.

Life Sciences

Dr. Doty described the life sciences as in a state of vigorous growth and likely to remain so throughout the remainder of this century. He noted there have been 5,000 PhDs per year in the life sciences over the past half dozen years in comparison with declining numbers in the physical sciences and engineering (3400 and 2400 respectively in 1976). Thus while he could find no consensus on what discoveries will be made 15 to 20 years hence, he emphasized that the field is alive with the potential of discovery and utility.

General Augerson characterized the US man in combat. The soldier is no longer from the small town or farm who is comfortable out of doors. But rather, few will have worked with cars, fixed radios or fired a weapon as youth. For many, all impressive technology is imported (such as Japanese electronics) and domestic goods are subject to recall. Typically, equipments are undersupported, and supply austere in the extreme. If the war is in Central Europe there will be concern about dependents, if elsewhere, a national consensus may be lacking. Tactical dispersal, isolation in-fighting vehicles, and disrupted communications put serious barriers between the soldier and the supporting group with which he identifies. The equipment imposes acoustical, acceleration, thermal and toxic stresses close to tolerance limits. Intense, sustained around-the-clock combat in fluid and confusing circumstances can be expected. With no sleep people become ineffective in about three days, units and command sooner. Sustained military performance is possible with three hours of sleep per day.

Regarding lethal, toxic or disabling chemicals and drugs Dr. Doty doubted lethal agents would become any more lethal than present nerve gases. Nonlethal toxic or disabling agents are somewhat different. Nevertheless for them as well as the lethal agents he said the problems are not with the deficiency of the chemical, but with the delivery system. The uncertainty is in the domain which they will affect, and the duration of their concentration (or lethality). Similarly,

the biological warfare agents--bacteria, toxins and viruses--already have a high specific lethality roughly comparable on a weight basis to a fission weapon.

General Augerson said this topic could not be dismissed so easily. The Warsaw Pact (Soviet) doctrine emphasizes the offensive with mass breakthroughs, relentless exploitation, replacement by units and disruption of the enemy rear. The Pact appears to have an edge in defensive arrangements and are better prepared therefore to exploit offensive opportunities of lethal chemicals, toxins, biological agents, and nuclear weapons. The conventional challenges are formidable alone; the sudden massive use of nuclear, biological, chemical (NBC) weapons can be expected to have a disruptive psychological effect on US and Allied forces. Earlier studies of disasters showed no more than 25 percent of those involved to be promptly effective, others taking more than a day to become active.

There has been little success in having NBC considerations assimilated into US military doctrine and practice. The equipment status further erodes any confidence. US personal and collective chemical warfare protective equipment availability has improved recently, but not up to United Kingdom standards. Vehicles do not have engineered-in-collective protection other than filtered air for crew masks, unlike most other countries. The US acknowledges a retaliatory capability with chemical weapons, but there are no US biological warfare weapons. The detection kits for chemicals have sensitivities above the level where effects might take place. There is no BW detection capability. Units have radiation counters, but they are not standard on vehicles. Limited amounts of vaccine for certain possible BW agents exist, but not for all the more promising candidates. Unlike several friendly countries the US has no deployed prophylactic systems for chemical agents. There is no deployed radiation protection drug for US forces.

Offensively he thought attention in the future may go to applications of microencapsulation. [redacted] 25X1

may be available thereby causing high biological effects with very low doses. [redacted]

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Defensively, he noted that protective material will be more important ultimately than the medical effort. He foresees a step improvement in current semipermeable protective clothing, perhaps incorporating neutralizing chemicals in the fabric rather than absorbers and a more integrated protective system, closed or semiclosed, with a helmet that gives full seal, good vision, and a degree of protection against fragment, laser, and nuclear flash. This will be more feasible as more personnel operate from vehicles or shelters. Detection, through advances in instrumentation, theoretically permit far greater sensitivity, e.g. mass spectrometer and laser-induced fluorescence, but the problem is the diversity of the chemical-biological threat. A full biological system including intact animals would give more confidence. Prophylactic drugs and vaccines will be pursued--but slowly. The constraint is the penalty in impaired-operational performance.

Dr. Doty said gradual improvement in drug-induced relief from pain could, with the now-serious inquiry into the mechanism of pain, produce substantial alternatives to analgesics. Progress in producing extended sleep, hibernation, or even reversible cryogenic arrest is unlikely because so little advance is being made in understanding and intervening in the central nervous system in reversible ways.

General Augerson summed his remarks by noting the adaptability of people to chemical weapons in World War I, and indeed the ability to continue WWII operations in the presence of high casualty densities, suggests that we could be capable of prevailing if such weapons are used. Today the difficulty of detecting chemical, biological agents or radiation without special equipment is a major psychological problem affecting the way troops feel about such threats. Defensive, or offensive, developments will be a waste of money if attention is not paid to training, discipline, indoctrination and practice on the part of military personnel and commanders so that NBC operations are drilled to where they are automatic and assimilated fully into military operations.

Dr. Doty addressed the topic of genetic engineering. He saw genetic engineering in this century limited to exploiting the transfer of genes from higher organisms into bacteria and viruses in order to manufacture important products of the higher organisms, rather than the introduction of genes from one higher organism into the stem cells of another. The latter, schemes of significantly changing humans, seems a very long way off. He pointed out that the combatants for this century are born or will be within the next five years.

Dr. Doty said the apparent mismatch between the onrush of the life sciences and the modest impact in matters relating to national security was cause for question. There is no counterpart in the life sciences to the R&D community in the physical sciences constantly innovating and applying new developments or discoveries--except in limited areas such as the pharmaceutical industry. He thought the question serious enough to be examined in a deeper manner than this brief forecast permitted.

Naval Combat

Surface ships and submarines are presented in that order in this section. Not large ships, but rather smaller advanced surface vehicles were the subject. New possibilities for undersea vehicles for combat and as work vehicles were presented and discussed, as well as new ideas for submarine operations.

Mr. Mantle presented candidates for advanced naval surface vehicles for the year 2000. These were hydrofoils, air cushion vehicles (ACVs), surface effect ships (SESs), small waterplane-area twin-hulled (SWATH) ships, planing craft and wing-in-ground effect (WIG) vehicles. Normally these are sized in the 1,000-3,000-ton class, with the SES and SWATH also considered as possible aircraft carriers. Several of these offer revolutionary performance features such as calm water speeds up to 100 knots (three times today's displacement ships), seakeeping features that would virtually eliminate seasickness, and impressive maneuverability. For example, the 40- to 70-knot speed of the hydrofoil, ACVs and SESs offer the opportunity of an ASW vehicle to sprint/listen ahead of a convoy. The SWATH has the sea-keeping characteristics of much larger ships and thus could serve as a mini-carrier since two or three could be constructed for the cost of one large carrier. However, the small high speed vehicles cost the same as large medium speed displacement ships

(3,000-ton displacement, 80-knot high speed ship costs as much as a 10,000 ton 35 knot displacement ship) and thus new roles rather than competing roles need to be explored for such high speed platforms.

Speed, seakeeping, size and cost are the major considerations. Technological opportunities exist to extend capabilities or overcome some of the recognized shortcomings, for example a variablegeometry foil can add a 70-knot dash capability to a 50-knot cruise hydrofoil at no loss in seakeeping capability, supercritical hull designs can eliminate pounding at the bow for planing craft, and slim designs can give the SES an ability to operate at low speeds similar to that it possesses at high speeds.

He said introduction of these vehicles into the fleet is unlikely to be the result of a technological achievement, but rather the result of experimentation with smaller and slower versions of these vehicles. Fleet use of ACV and SES at 2,000 to 10,000 tons, but 40 to 70 knots in lieu of 100 knots, and hydrofoils at 200 to 2,500 tons and 50 to 70 knots would provide the opportunity to test the concepts and develop military applications. Other navies operate these type vehicles in numbers greater than the conventional US Navy fleet today. The Soviets have a large amphibious force of ACVs together with over 800 hydrofoils combined in Soviet Navy and civilian operations. Similar experience, rather than any specific technical development, is likely to develop a military role for these vehicles.

General Gray drew attention to the advantages these high-speed platforms could have for a mobile force to land 1,000 miles away, overnight, in weather of our choice. Support could be provided by platform use for VTOL, surveillance, and communications. Used for a precursor force or time-limited operation, these vehicles could offer unique advantages.

The WIG is normally not thought of as a naval surface vehicle, but it offers speeds of 200 knots near the surface. Flight over calm water has been demonstrated, but flight close to irregular seas has yet to be solved satisfactorily. Design possibilities for reduction of catastrophic results from wave crashes do exist, as does the possibility for large-wave avoidance once data of local oceans conditions are routine. Even though the technology is embryonic, the WIG is possible by the year 2000.

The discussion identified military uses for a large WIG such as rapid transport for crisis teams to remote locations, deployable launch platform for cruise missiles, deployable platform for air-defense surveillance and anti-air missile launch, and deployable platform for ASW surveillance and attack. The discussion also brought out additional possibilities for the SWATH vehicle; namely, that because of its small size and excellent sea-keeping capabilities both at rest and under way, it has high potential as a support vehicle for undersea work vehicle operations.

Admiral Martell characterized the differing submarine philosophies of US and USSR operations. Our Trident program involves maximum reliance on acoustic concealment and the incorporation of long-range missiles to expand its effective area of patrol by almost an order of magnitude. The US is relying on a strategy of wide ranging concealment; the USSR, as implied by the Delta design, relies on a strategy of limited mobility in a protected enclave.

He noted that as a baseline we have the technology in hand today, if we should choose to apply it, to decimate the Soviet submarine force if it deploys to the open ocean. This capability depends on exploitation of signal intelligence and acoustic detection over wide areas of the oceans and the capability of ASW aircraft and attack submarines to re-acquire acoustically and attack successfully with acoustic torpedoes. Naturally our capability is vulnerable to such countermeasures as quieting of Soviet submarines and destruction of our surveillance assets, air-attack on our ASW aircraft, and sensors, weapons and speed of Soviet active submarines in a one-on-one encounter with US submarines.

Technology can be effective in reducing these vulnerabilities, especially in offsetting quieted submarine designs. The reduction in cost and complexity of computation should permit adaptive filtering against noise, wave front discrimination, or precise compensation for offline arrays, and practicable airborne or in-buoy beam forming of randomly positioned buoys. A gain of 20 dB by the year 2000 appears possible, along with the possibility of rapid replacement of surveillance assets as they are neutralized or destroyed. Continued ability of the US submarine to detect Soviet submarines locally can be achieved through hull-borne sensors and the addition of towed arrays. Survivability of ASW aircraft can be achieved through antiair weapons or reduction

of on-station time to about 20 minutes for acquisition, localization, and attack by a high degree of functional automation and development of fast localization algorithms.

Nonacoustic techniques (including magnetic anomaly detection, turbulent wake, and electromagnetic emissions), along with active acoustic devices, are limited to detection and tracking at a few to tens of miles and have little prospect of providing wide-area surveillance. These are applicable to localized protection of enclaves and possibly to assist area coverage when deployed in barriers or restricted geographic areas. The Soviets have concentrated on the nonacoustic and the active acoustic. This does not mean we should pursue mirror technologies, but it is incumbent that we actively investigate these thoroughly for protection of our submarines and against possible deterioration of our acoustic advantage. He made clear that as the philosophy of Soviet submarine warfare is difficult to understand so should it be unsettling.

Discussion did touch upon the strategic, or concept and operations of nuclear deterrence; and the tactical as it applied in the past to operations concerned with merchant convoys, amphibious assault groups, or carrier strike forces. The difference in antisubmarine operations appears to be less in any fundamental equipment and methods which might be employed than in the time, place, and circumstances of the encounter. The antisubmarine submarine is new and potentially a powerful antisubmarine weapon system. Inadvertent attack on strategic submarines or "strategic assets" during tactical operations would naturally be serious cause for concern.

Mr. Chapman described the potential for a new type of undersea weapon--an extended-endurance, high-performance, extremely quiet, small submersible. One application would be that of a self-controlled "robot" vehicle for covert trailing of submarines, standoff ACINT/ELINT, and covert probes of coastal and harbor defenses. A second is a 20-ton, one-man fighter that would be launched and retrieved by a larger submarine which could serve to search a broad front and localize targets for attack by the larger submarine. A third is that of a 60- to 100-ton, three-man interceptor that might be based in barrier or forward areas for quick reaction against any surge deployment of Soviet submarines. Fourth is the obvious application to a high-speed torpedo.

The technologies are those of low drag laminar flow hydrodynamics and high efficiency closed cycle chemically fueled power systems. The latter include the fuel cell, the closed Brayton cycle gas turbine, the Stirling engine, the Rankine cycle stem turbine, the lithium seawater cell, and a variety of high energy density batteries. The benefits of laminar flow achieving an order of magnitude less drag below that of conventional underwater bodies are such that propulsion for a torpedo could be reduced from 140 horsepower to drive the conventional torpedo at 55 knots to less than 20 horsepower. The fundamental appeal of the small submersible is that it could be produced in large numbers by production line techniques. The "robot" has approximately the same complexity as the MK48 torpedo--now produced at an incremental cost of $1 million each. Allowing for greater complexity and smaller production runs the "robot" could be produced for $5 million a copy. Similarly, the fighter cost should be about $30 million a copy and the interceptor about $50 million a copy.

Present application of laminar flow is limited to the forward or nose portion of the torpedo--and potentially the submarine--in order to reduce the flow noise in the vicinity of the sonar transducers. Expendable laminar flow targets and experimental towed vehicles also exist. The extension to these small submersibles are within grasp. The most ambitious objective would be application to the full-size submarine or portion thereof. This is considered well beyond the state of the art.

Dr. Talkington described the expected increased use of the undersea environment, and its implications for undersea work systems. [redacted] 25X1

Key technologies to these uses include optical fibers with very low volume per length, which will allow totally new innovation in cable laying and handling to fill the needs of sea-floor transmission cables, of undersea vehicle tethers, and of small expendable links to moving vehicles. Signal processing techniques that will permit simulated

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km. High-energy density lithium thionyl/chloride batteries of 300- to 500 watt/lb which will provide long endurance power for untethered remotely controlled undersea vehicles, manned submersibles, and remote sensors. Solid-state electronics, which will not require pressure protection, can be used to eliminate heavy containers and the problems of pressure leak failures.

The discussion brought out several important points relevant to the future undersea environment. First, undersea technology is being rapidly advanced by commercial interests, as well as those of the government, in support of offshore operations and potential deep seabed exploitation. Second, both offshore and deep-sea operations create noise levels in the sea that may shield submarines from passive acoustic detection systems. And thirdly, the Law of the Sea boundary changes restrict submerged submarines from areas of tactical environmental or intelligence importance, and thereby create a further need for remotely controlled unmanned undersea vehicles operating from support platforms at safe distances. Clearly, the available technology and the need are likely to give strong emphasis to remotely controlled undersea vehicles to perform a wide variety of missions.

Strategic Technologies

Strategic systems per se were not presented nor discussed. Rather, selected technologies for strategic systems--guidance, cruise missile penetration aids, and hypersonic flight--were topics of the colloquium. The implications for strategic technologies of a non-mutual assured destruction strategy appeared to be vast. However, time was not available to discuss these to any extent.

Dr. Shulman contrasted present-day capabilities for guidance of ICBM, SLBM, and aircraft/cruise missiles with the potential of future guidance technologies. He cited the lack of agreement between flight test and theoretical accuracies for our ICBM; and the criticality of accuracy given our relatively low-yield warheads. He argued that there is little reason to expect significant improvements from today in all-inertial accuracies, and thus other techniques must be employed.

Radio systems used as an aid to the basic missile inertial guidance can remove initial condition errors and to a large extent reduce dependence on the performance of the inertial system. The Global Positioning System (GPS) is a radio guidance aid that differs from 1960 systems only in that the electromagnetic signals originate from satellites rather than from ground stations. A dedicated, inverted GPS system with transmitters placed at random in the northern half of the US would be less vulnerable to countermeasures or to direct attack. CEPs through such radio aids can be reduced to 350 feet for the ICBM. Similar advantage can accrue to SLBM and aircraft--since the limitations of initial conditions are removed.

This gain is significant. Further CEP reductions necessitate maneuverable reentry vehicles and terminal guidance where the possibility exists to bring CEPs to below 100 feet, but at a cost in weight and volume available for the warhead and at a further cost of increased complexity and possibly reduced reliability. He noted the USSR has a lead over the US today in ICBM PK, achieved by larger weapon yield with less accurate missile guidance.

Dr. Vander Stoep followed with description of correlation techniques for cruise missile terminal homing--that is guidance based on comparisons of ground signatures sensed over wide areas with stored replicas of these signatures. He described three techniques: TERCOM, which uses terrain height variations measured by radar altimeter; synthetic aperture radar (SAR), which uses high contrast radar features; and range measurements made of pre-selected fix sites. Inertial navigation systems perform primary guidance between correlation updates. CEPs of 10 to a few tens of feet are projected for cruise missile applications.

He identified the key technology as maps prepared with high accuracy and signature fidelity with errors no greater than 5 feet--and accomplished in coordination with correlation algorithms and sensor developments. Developments of millimeter wave, infrared and optical frequency applications are likely to have high payoff. He considered current inertial navigation systems to be adequate for use with the correlation systems, but reduction in their cost could be of major importance.

Mr. Nye surveyed several technological possibilities for future cruise missile developments. Current Soviet air defenses are estimated to have a marginal intercept capability against today's cruise missiles. Modifications and additions

to the Soviet surveillance, SAM, and interceptor systems over the next 10- to 20 years could significantly change this picture. Thus he focused on those technologies important for cruise missile penetration and not on those of range, accuracy or warheads.

Penetration by evasive maneuvering is not compatible with cruise performance; ECM and decoys heavily penalize the missile with higher signatures and loss of usable volume; high supersonic/hypersonic speeds have a high cost and cause significant loss of range. More positively, a supersonic final stage might be employed to carry the warhead through the terminal defenses; penetration at attitudes of 200 feet is a partial answer; and on-board passive threat warning sensors can permit individual missiles to curcumnavigate defense zones. He said the technology which offers maximum leverage are those which reduce observables, (IR, radar, visual, and acoustic) as the cruise missile is particularly suited to this design.

Radar signatures of one-thousandth of a square meter are foreseen with designs employing flush inlets, blended body, and liberal use of radar absorber in the edges. Considerable IR reduction can be accomplished through cooling and shielding of the engine, although even heated area surfaces may be significant sources to advanced mosaic IR sensors. Critical to signature choices are specifics of defense systems, experiments and models of suppression results, and test ranges capable of evaluating real effectiveness.

The discussion brought out counterviewpoints, e.g. descriptions of potential radar capabilities that might be a match for even these low-observable vehicles. Dr. Skolnik noted that radars can see birds and that's the size object being described, the problem is fundamentally one of response time to intercept. He saw more problem in radar detection and track of a high speed (Mach 3 to 4) missile. Nevertheless a cruise vehicle "invisible" within defensive weapon response time was acknowledged to be a real possibility for the future.

Concern over real versus analytically determined penetration possibilities brought the discussion to test ranges. Test ranges exist, however, these were considered inadequate to develop the data and to examine the penetration possibilities and problems applicable to the next generation of cruise

missiles. Little data exist for low cross section operations in a multipath environment. Exercises are canned, unlike true two-sided games where unrecognized problems can be identified. Range development and use was flagged for attention.

Arguments were made in favor of supersonic speed as a necessary complement to low observability in order to ensure the defensive system could not be responsive. Supersonic and hypersonic speeds for cruise missiles were discussed. Speeds of Mach 2 to 3 coupled with low-observable designs were advocated for solution to penetration requirements, as were speeds of Mach 4 to 6 even without low-observable design. The penalties of cost and range were recognized to be sizable. Furthermore, design for flight at speeds above Mach 4 would clearly require a propulsion and materials technology program not now under way. Thus while the possibilities exist for supersonic/hypersonic cruise missiles within the next 10 to 20 years, most doubled this to be a likely development.

The military uses of manned hypersonic flight were presented by Mr. Combs to be as a follow-on to the SR-71 reconnaissance mission during both crisis and postattack, as a launch platform for supersonic and/or hypersonic maneuvering cruise missiles, and as a launch platform for anti-satellite weapons. Argument was presented that the SR-71 at Mach 3.2 with penetration aids may not be survivable against Soviet defenses beyond the early 1980s, but that an attainable vehicle for flight at Mach 4.5 could be survivable in this mission into the 1990s.

Temperature limits and propulsion designs currently limit growth of a manned vehicle beyond Mach 4.5. Thus a focused technology development program was seen as necessary for attainment of these higher speeds.

Attitudes expressed in discussions were passive toward technical feasibility and military utility. A hypersonic flight vehicle was expected to be extremely high cost. Yet, until there is a clear commitment of military need, no one knows if the cost would be acceptable or non-acceptable. Development of a next generation hypersonic vehicle awaits resolution of these questions.

Space Systems

Dr. Rechtin presented the surprise-free technological future of space systems as the continued evolution by both

countries toward increased real-time military support for strategic and tactical weapons systems--that is, surveillance, targeting, cuing, navigation, communications, command and control. This includes optical surveillance of strategic and tactical systems as described by Mr. Justice; includes the global positioning system described by Dr. Shulman, as well as tactical position location in a jamming environment; and includes communications for battlefield or naval sensor readout, RPV control, and trooper communications.

This means both the US and the USSR will become increasingly concerned about space access and the consequent needs for active and passive defense against both physical and electronic attack. He made the point that survivability for space assets is probably as achievable as for anything else, if not greater.

Passive defense measures are already being implemented by the US and USSR. Examples are nuclear and laser hardening, protection or elimination of solar cells, encrypted jam-resistant commands and communications, spare satellites in orbit, provisions for satellite maneuvering, tracking of all potentially threatening satellites, attack-warning systems, proliferation of ground command stations, satellite cross-links, and possibly silo-launched space boosters. By 2000, active defense systems of the US and USSR could include ground-based lasers for low-altitude kill, both fly-by and positioned space-borne lasers for satellite kill, and space borne lasers for selective attack upon earth stations. Ground or space-borne beam weapons are considered a much more distant possibility, as is a system of large laser weapons capable of rapid multitarget kills.

He described several developments which may significantly influence space systems--for example, the importance very large structures can have in space by 2000. They can provide for the equivalent of an AWACS or BMEWS in space for radar detection and track of aircraft, cruise missiles, ballistic missiles and space objects. They can provide for operation of multistatic detection radar using space-borne passive reflector arrays. They can provide for spaceborne jamming of tactical ground radars and communications. They can provide localized illumination of night battlefields through reflection of sunlight. Developments in materials, structures, and cheap transport are needed to realize these potentials.

He said the role of military man in space is speculative at this time; e.g. survivable command-control, special strike/reconnaissance, or as adaptable surveillance/communications center. The role in the 1980s and 1990s is probably limited to research, development and support functions based on the use of the space shuttle.

Dr. Weiss described laser propulsion. Laser propulsion is a thermal rocket system that uses beamed energy to heat a low molecular weight propellant, such as water vapor and nitrogen. The amount of power provided would no longer be limited by the size or efficiency of the onboard power supply. Power is dependent upon the ability to focus and contain energy supplied by the remote source. He projects for laser power, 10MW in the early 1980s, 100MW by 1990, and hundreds of megawatts to gigawatts available before the year 2000.

The potential military applications of laser propulsion are derived from either unique or cost-effective capabilities. A megawatt laser propulsion system could launch an IRBM every 1.5 minutes. A 1,000 Mw system could make three ICBM launches per minute--100 launches in the flight time of a missile. The 100 Mw system could launch 75 400-kg satellites in one day--to give highly redundant communications or hundreds and thousands of minisatellites or decoys as countermeasure to the ASAT threat. Lastly, a 100 Mw system could launch 10 million kg into orbit each year, making feasible construction of large space structures such as space defense systems and solar power satellites, for power transmission or defensive purposes.

He noted research and development is needed in beam propagation, extreme pointing and tracking requirements, the problems of maximum range imposed by diffraction optics, large scale optical systems, and large electrical power sources. However, most of the capabilities of this radically different propulsion technique are expected to be demonstrated on some scale in the next two decades, with one or two prototype developments. He considered the prototype development equally likely in the US and USSR.

The completeness of the space systems review precluded further discussion of the systems and their applications. However, several did note that while workable survivability may be attainable it would likely involve severe trade-off of otherwise desirable performance and thus might not receive the obvious emphasis placed upon survivability by Dr. Rechtin.

The number of Soviet launches and the 4-to-1 launch rate in comparison with the US were discussed. Dr. Rechtin presumed for his projection a decrease in Soviet launches based on the assumption that the Soviets would achieve greater on-orbit reliability. This view was not contested, but some suggested that the Soviets do gain a military advantage through their capabilities for frequent launches.

The discussion contrasted the ready market for technologies in space systems with the problems of exploiting technology in other military equipment acquisitions. Technology as the driver, user dedication, and numerous other differences were all offered as explanations of the contrast. However, it was noted that as space systems are used more extensively in applications such as ocean and battlefield surveillance, the problems of integrating the multiple assets and the multiple users may well face assimilation difficulties not unlike those faced in other acquisitions.

Materials/Physical Sciences

Materials science is to a considerable degree driven by need. Thus extrapolation into the future can proceed with assurance that many gains are thereby recognized. By contrast, quantum step progress is more likely from opportunity driven research. These presentations and discussions of materials, and even more those of geophysics and ocean science, should be examined for the opportunities they may create.

Dr. Laudise reviewed electronics materials research. He noted that in almost all aspects the US is leading with strongest competition usually from Japan, sometimes from Western Europe, and with rare serious competition from Eastern countries. Silicon will remain the mainstay of electronics over the foreseeable future.

The future of computers and microprocessors (discussed earlier) depends on progressing from large scale integration (LSI) to very large scale integration (VLSI). He said optical or x-ray exposure through an electron beam mask and eventually direct electron beam exposure should provide for this scale of integration, but at likely higher cost. Magnetic bubble memories, which are expected to entail fewer process steps and thus fewer fabrication failures, may eventually provide a cheaper alternative.

He noted that optical fibers were already at a high state of development. More recently the emphasis in research

and development is on highly reliable optical sources beyond one-micron wavelengths. From this, low-loss optical communication systems are likely in the 1980s with concomitant development toward optical integrated circuits. He believes the move from discretes to integrated optics will not take as long as it did from the transistor to integrated electronic circuits.

Basically he described preparation activities as having become more sophisticated. Molecular beam epitaxy (MBE) allows the preparation of almost monoatomic layers of programmed composition. Thus the possibilities for nonequilibrium structures and materials previously unobtainable are manifest. The detectors for the space and tactical surveillance described by Mr. Justice are one obviously important application.

Dr. Bement addressed the matter of other materials, but first noted that optical sensors and diphasic composite materials offer, as undersea acoustic sensors, the potential of order-of-magnitude improvements in acoustic response and greatly extended depths of application. Even such currently available materials as fiber optic hydrophones can provide sensitivities far greater than required for underwater use.

He then described structural requirements of large space optics, where adaptive servo-activators may compensate for otherwise unacceptable large deflections; but where the availability of low-expansion high-stiffness optical materials may reduce these numbers and thereby simplify this system. He cited carbon-graphite composites, ceramic composites, and glass-matrix composites as possibilities to satisfy these materials needs. Similarly, metal matrix composites are likely to serve the needs of the large-scale deployable and erectable space structures of the future such as the large radar antennas.

Dr. Bement drew attention to other materials developments, especially those of basic power systems. He cited the completed test of an all-ceramic uncoded turbine rotor operating at 2,500°F inlet temperature, which potentially could provide a fuel savings of 8 to 28 percent in cruise missile gas turbine applications. Moreover the ceramic materials used to date do not even represent near-term improvements in the state-of-the-art. He noted that for electrical machinery the system for collection of current dominates the geometry and size of new equipments. He cited

developments of monolithic brush collectors for high power density electrical machinery, which will allow conventionally cooled machines to match superconducting machines in size and weight. He cited materials impact upon design simplification, or changes not easily seen, such as the increase in wear-life of splines to the point where they never need to be replaced in ship or submarine.

Dr. Kear gave an overview of developments, old and new, in laser materials processing technology. Laser welding already has many applications. The welding of ring frames to hull sections alone shows the possibility of reduction of over 60,000 man-hours and thus $1 million per submarine.

Laserglazing (surface melting followed by rapid solidification) is a relatively new technology with many possibilities. Bulk structures such as discs and drum rotors can be built up incrementally by laserglazing one thin layer on another. This gains a completely homogeneous, flaw-free structural part, is natural for computer control and near-net shape bodies, and can be combined with thermo-mechanical treatment to give material microstructures otherwise unattainable.

In-situ surface treatment to attain high temperature-corrosion resistance as well as shock hardening to improve fatigue properties are other examples. Dr. Bement added that laser treatment of aluminum can gain 30 to 40 percent in strength and 100°C in temperature use--so it is almost a new metal. Ultimately, Dr. Kear believes pulse annealing, ion-implantation, and laserglazing will develop into an integrated new technology for the surface treatment of materials with a wide range of structural and electronic applications.

Discussion brought out the possibilities for field use of laser welding (already used for pipelines) and laserglazing surface treatment. These were seen to be of great potential for field maintenance. Dr. Bement added further to field possibilities. He described the possibilities for in-field "cloning" from polymers or steel of replacement parts for existing or captured equipments. Three dimensional photography with autodigitalization would control casting of parts for automatic weapons, aircraft/missile or orthopedic needs. He noted this application might be put to intelligence purposes since similar photos of enemy equipment could be put onto digital tape for later reproduction.

Dr. Anderson stated geophysics is central to a few specialized military problems, such as missile guidance (gravity field) and weapons testing monitoring (seismology), but is also involved in such general problems as weather forecasting and control and submarine navigation, detection, and evasion. He emphasized the advances expected in geodetic instrumentation and technology including the multiple satellite sources. The results will show in missile accuracies, precision updating of ship and aircraft inertial systems, and so on. He believes DOD geodetic self-reliance can be expected to increase and argued for more interaction with others to pass on the gains in knowledge.

Separately, he identified a number of related developments of importance to national security but perhaps only indirectly to military capabilities. The direct detection of hydrocarbon resources by shear wave techniques should be industrial practice during the 1980s; and thereby the possibilities for the cheap discovery and early exploitation of these resources. The routine prediction of major earthquakes will make possible either disaster preparation or, the opportunity for covertly testing nuclear weapons. Routine six- to 10-day weather forecasts will be as good as today's two- to three-day forecasts; and along with a more basic understanding of weather modification, may come the technology to increase precipitation. Lastly, he noted materials are now being fabricated at one to 10 megabar pressures, which opens the possibilities that these new materials will possess unique physical and electrical properties.

Dr. Wunsch cited two major areas where ocean science relates to national security: the knowledge of the fluid ocean on the acoustic and operational environment of the Navy, and knowledge of the relationship between the ocean and possible climatic changes. He emphasized the extent to which we are now ignorant of the ocean as compared to the atmosphere. Now, a very few observations and a rudimentary knowledge of physics form our knowledge, but in 20 years he expects a reporting network much like now exists for the atmosphere and a real understanding of ocean weather and climates. Acoustic sounding, satellites, and advances in computer techniques will make this possible.

He predicted that in 20 years we will have the capability for large-scale global monitoring of ocean weather systems with a forecast ability equivalent to what is available today for the atmosphere. This will have an enormous

impact on vessel routing, ASW (acoustic propagation and tracking) capabilities, tactics, and upon weather-climate forecasts. We will also have greater understanding of the role of ocean circulation in climate change. It is now believed the ocean carries as much heat poleward from the equator as does the atmosphere, but where and by what mechanism? Clearly with this magnitude, the ocean plays a major role in regional and global climate flux. The understanding may enable the forecast of major changes far enough in advance to alleviate catastrophic outcomes.

Energy Weapons Applications

Two items were presented and discussed as unique energy weapons applications: namely, the charged particle beam and the electromagnetic gun. Both offer revolutionary concepts as killing devices. A third unique energy item, that of laser propulsion, is contained in the discussion of space systems.

Mr. Kassel detailed the applications for particle beams, or more specifically charged particle beams (CPB), of high currents and high energies and related these to research and development under way today. Particle beam devices may provide rapid delivery of high energy at high density with considerable precision either in the form of material particles (electrons, protons, heavy ions, or neutral atoms) or after conversion as photons (x-ray, infrared, or microwave radiation). A number of government and private laboratories are designing and building large one-of-a-kind CPB accelerators and associated equipment intended for a variety of scientific and technological applications. CPB devices are a possible alternative to lasers in pellet fusion research and are unique as tools in the simulation of nuclear weapons effects and in radiography for nuclear weapons research.

The CPB as a weapon has the potential of superceding mechanical systems limited by inertia, e.g. response time of milliseconds instead of seconds. However, he emphasized that critical deficiencies in the technology exist. These are switches capable of handling ultra-high-power pulses in nanoseconds; beam stability within the accelerator; and external beam conditioning, aiming, propagation and position sensing. These are serious enough to cast doubt on the basic technical practicality, yet are feasible in principle. Experimental machines capable of producing energy levels of operational weapons (e.g. 50 MeV) are needed to resolve the questions. Dr. Davis noted a 100-MeV facility is in our R&D program.

Other questions or needs of course exist. Beam interaction with the target is also unknown although simulated. The size and weight of the accelerator system must be reduced significantly for many military applications.

He cited possible nonweapon applications of CPB devices. An electronic countermeasure system using the radiation cone effects of an electron beam is possible and would require minimal beam length and aiming accuracy. A nonaimed beam weapon designed to produce a large radiation dose over a tactical area is possible and would not require propagation of the beam in air when used at short ranges. A Soviet has advocated the use of high-power beams in pipes as the most efficient means of long-distance transmission of electrical power. Soviet experiments have used electron beams to test brittle destruction of materials, during which they found that qualitatively different physical processes take place in materials--leading to possibilities for far-reaching phenomena in solid-state technology. Some US researchers have proposed high-power electron beams as a high-speed rock drill.

The Navy Chair-Heritage program was described during discussions. The objective is an aimed short-range (1 to 4 km) CPB weapon projected in air. Mr. Kassel described the energy to be delivered in a single 20 nanosecond pulse as equivalent to that delivered to the target by the 105 mm tank-gun round. Some questioned the beam-target interaction and the ease of countering the beam. He said enhanced effects such as removal of material well beyond the beam radius is expected as well as collective effects within the material, e.g. secondary electrons. If this is correct then the CPB can defeat any kind of missile hardening measure such as a high-Z shield.

Some discussion centered on what we know of Soviet work. Mr. Kassel said the Soviets do have a major pulse power program. Furthermore, the Soviet work is strong in exactly those areas needed for weapons application--whereas US work to date has not been pointed toward military applications. Thus while we can surmise the Soviets have a military program we do not know what type of program it may be, nor do we know what observables in the atmosphere we should expect to see.

Dr. Fair initially addressed chemical propellants and the gains from associated work on insensitive explosives (see Kury), liquid propellants, and from capitalizing on

advances in fiber optics and laser technologies for ignition systems. However, the potential for more than evolutionary change he identified with the electromagnetic gun. The concept would employ a projectile with a magnetic coil propelled out a tube by a linear electric motor. A prototype exists. The "Mass Driver" was constructed by an instructor and students at MIT to demonstrate outer space transport, but has about one-tenth the energy of a small mortar. The technology exists to undertake a moderately scaled gun version.

He cited the potential advantages of an electromagnetic gun. Some of these are precise control of projectile energy; elimination of gun tube wear, flash, smoke, etc.; rapid fire; ease of supply; and no propellant charge, no propellant surveillance, etc. The propulsion could be provided entirely electromagnetically or in a hybrid system where some electromagnetic energy is used as an adjustment--with different degrees of these advantages gained.

TABLE OF PROJECTIONS

This table presents in bullet form the projections from the prior pages of this Technological Futures section.

Data Processors

- Million bit memory chip by late 1980s.
- 100 x cost reduction by late 80s.
- 1-5 MIPS @ $50-100 by late 80s.
- Entire systems integrated on chip in 1990s.
- Single processor machines to 300 MIPS by 2000.
- But multiprocessors for 1000 MIPS--application to weather, oceans, differential equation calculations.
- Input-Output will not advance much by 2000, except direct sensor-processor interface.
- Distributed processing and fiber optic links commonplace.
- Microprocessors with piecemeal updating will eliminate technological obsolescence for defense systems.
- Monitoring execution of a plan.
- Software will be thrown away.

Surveillance

- Radar to remain principal surveillance sensor.
- Non-cooperative radar IFF for air targets--but system may not be practical.
- SAR imagery of terrain and targets tactically prevalent.
- Concentration on improvement of operator-display interface.
- Radar systems of 1990s to operate for years without functional failure.
- Solid state phased-array power increased 100 x by 2000.
- Coordinated use of same hardware for radar, jammer, and secure data link.
- Microwave digital processing.
- Bi-static radar value questionable.
- Mirror scanned antennas in lieu of phased array.
- OTH radar for over water detections and sea state measurement.
- Optical scanning replaced by staring mode operation.
- Optical focal plane arrays (with processing), programmable spectral filters, and adaptive optics will make possible the spaceborne detection of subsonic aircraft and small missiles, ships, and armor formations by 2000.

- Radar satellite in mid-80s will be capable of surface ship detection, but not classification, and transmission directly to the tactical requestor.
- OTH targeting of surface ships in 80s.

Land Combat

- Tactical aircraft to improve considerably in all speed ranges--with potential for tradeoff with payload, low observable design, or maneuverability.
- VTOL range-payload performance to be as good in 1990s as current CTOL.
- Man portable mini-RPVs will be future direction if use is to be widespread. Needs convincing operational experience plus senior level commitment.
- Multisensor integration for battlefield target picture.
- No forward observers required for DME directed missions.
- Netted air defense system of both air and ground radars.
- No theater IFF solution in sight.
- Air defense to rely on short range missiles and guns.
- Insensitive explosives and propellants will remove safety constraints.
- Short-range missiles to use millimeter wave guidance to gain night/bad weather operation.
- Focal plane IR correlation trackers to be used in fire and forget indirect-fire sub-munitions delivery.
- Continuous operations is the design problem.
- Infyonics concept to maximize exploitation of new technology.
- Radical change in logistics is biggest gain.

Life Sciences

- Little success in assimilation of NBC considerations in US doctrine and practice contrasts with emphasis given by USSR.
- Microencapsulation for dispensing CBW agents.
- Defensively, protective material more important than medical effort--step improvement in semipermeable protective clothing.
- Slow progress in prophylactic drugs and pain relievers.
- Genetic engineering not applicable to combatants in this century.

Naval Combat

- ACV, SES and SWATH surface vehicles depend upon a concept of employment, not technological achievement.
- WIG possible by year 2000 as transport, missile launch platform and surveillance platform.
- Acoustic surveillance gain of 20dB by 2000.

- Rapid replaceable arrays and random buoys to reduce vulnerability of destroyed assets.
- Non-acoustic and active acoustic undersea search techniques limited to few tens of miles--applicable to enclaves and barrier operations.
- Anti-submarine submarine new and powerful anti-submarine weapon system.
- Laminar flow and high density propulsion in small interceptor and covert submarines.
- Fiber optic undersea links in wide use.
- [redacted] 25X1
- Lithium 300-500 watt/lb batteries in undersea applications.
- Undersea work vehicles to have wide use.
- Noise levels from commercial undersea and offshore exploitation shield submarines from passive acoustic surveillance.

Strategic Technologies

- Little improvement in all-inertial guidance.
- Global Position Satellites (GPS) or ground based inverted GPS will remove initial condition launch errors.
- Terminal guidance versus reduced throw weight and reliability a questionable tradeoff.
- Cruise missile CEPS of ten feet using correlation guidance, if maps can be made to five feet accuracy.
- Cruise missile radar cross-sections of 10 square centimeters.
- Cruise missiles in sustained supersonic/hypersonic flight unlikely because of range penalty.
- No manned flight beyond Mach 4.5 without technology program to overcome temperature and propulsion limits.

Space Systems

- Space based support systems will acquire passive and active defense against physical and electronic attack.
- Space lasers likely, beam weapon not likely.
- Role for military man in space limited to research, development and support.
- Large structures in space.
- Laser propulsion to provide for rapid expansion of missile and space vehicle launches.

Materials and Physical Sciences

- Silicon to remain mainstay of electronics.
- X-ray and electron beam masking and exposure commonplace.

- Optical fiber and integrated optics commonplace.
- Molecular Beam Epitaxy to provide near-monolayers of programmed composition.
- Low expansion, high stiffness composite materials for large space structures.
- Monolithic brushes reduce size and weight of conventionally cooled electrical machines to that of supercooled machines.
- Wearlife of submarine and ship splines increased to point where they do not need replacement.
- Infield cloning from polymers or steel or replacement parts for existing or captured equipments.
- Laser glazing and machining to produce flaw free parts.
- Geodetic accuracies to improve steadily.
- Routine earthquake prediction facilitates disaster avoidance or covert nuclear test.
- Weather forecasts for 6-10 days as good as today's 2-3 day forecasts.
- Ocean weather forecasting as good as present atmospheric weather forecasting.

Energy Weapons Applications

- Charged Particle Beams, if critical technological advances prove possible.
- Electromagnetic guns will not have today's wear and signature problems.

STRATEGY AND TECHNOLOGY

The form future conflict may take is naturally an important consideration in determining which technologies are militarily significant. Military requirements and planning are frequently labeled as "refighting the last war." Thus conflict considerations were introduced on the basis of their plausibility without regard to compliance with mainstream forces planning.

Even then, Dr. Stevens noted that too much of past analysis has been constrained by overattention to plausibility. In response, he suggested that the unknowns of the future, such as those sampled in these discussions, argue for broad capabilities in US forces.

Ideally, these sessions would have characterized the environment to be faced. Instead the materials discussed and recorded represent pieces for consideration, not a full treatment. However incomplete, they do reflect significant views of prime considerations for future needs. A few examples were offered of how technical priorities might be altered, but much fuller treatment is obviously required.

Overview

Mr. Kahn in his overview of strategy and technology stated that the level of strategic debate in the US today is at least an order of magnitude lower than 15 years ago. He particularly noted US focus on strategic forces as if they were only to respond to an out-of-the-blue attack upon the US. Similarly, we think about NATO forces as if the Warsaw Pact were expected at any day to grab Europe. He argued that most people consider these the least likely, and they are correct; but our planning and force choices have yet to catch up.

He expressed no doubt that the USSR would like to control the world, but stressed that while the Soviets may believe it necessary to push history in their direction they are unlikely to rush it. He saw the Soviets' emphasis on strength as very basic. First, if a crisis does occur and they are strong, the other side will back down. Second, if

they overextend and get into trouble, their large superiority will rescue them. And third, Finlandization of Europe is possible through recognition of Soviet superiority. These indeed are cause for us to be concerned over their strength; but we need fresh views in our response, especially as we view the future.

He argued that war, if it is to come about will not be calculated, nor out of the blue, but rather from a period of tension, with accidents leading to escalation. He cited two critical considerations for examination of strategic forces; namely, what is our goal at the end of the war and what is the importance of evacuation.

He thought for conventional war the most important consideration was the recognition that a buildup of tensions, perhaps even "phony war," would precede major hostilities; and thus a period for mobilization would exist. His second point about conventional war was the need to look at our best systems differently--one side forgets something, the winner does not; all fortresses are invulnerable before the attack, only some are found to be so after the attack.

Dr. Rechtin summarized the sober view toward NATO warfare taken away by most. He said many past questions and dilemmas about Soviet directions had been clarified. The Soviets appear more predictable than we had thought.

The Soviets are thinking about World War II technologically extended; that is, continuous-nuclear-biological-chemical warfare. This is what they are set up to do. The message has yet to be passed to US technologists and systems designers, but it seems clear that we must responsibly design to meet this threat.

Non-Mutual Assured Destruction

Dr. Durbin said the contingency of massive Soviet attack out of the blue against the US, followed by immediate and massive US retaliation has been the cornerstone of US planning for almost three decades. Deterrence is attributed to this posture of mutual assured destruction (MAD) or balance of terror, as both populations are thereby held hostage. Each offense must be overwhelming and the defense emasculated. This situation may in fact be the correct one for force sizing and decisions on alert posture; but it is not the only situation possible and in fact is not even the most plausible.

Limited selective or controlled use of central strategic nuclear weapons has been publicly discussed in the United States since 1974. Yet it is unlikely that either the US or the USSR can obtain any meaningful unilateral advantage through limited use of nuclear weapons against homelands. Use of these weapons in a local theater, especially on the Soviet periphery, is likely to be met in-kind in the theater. Either situation is likely to result in the rapid search for de-escalation and termination, with concurrent concern for alert and monitoring.

The threat to use tactical nuclear forces to back up inadequate conventional forces in Europe has been the basis of the NATO posture for the same three decades. The relationship of these forces to those of the strategic forces has never been explicit even before the current concerns over the SS-20, cruise missiles and Backfire Bomber. Furthermore, how does the survivability of these theater forces, their mix, and their use after a massive exchange relate to the MAD concept?

Lastly, what is the outcome of a massive nuclear war likely to be? An examination of the capability for a Soviet first-strike counterforce shows it to be formidable, although not likely decisive. Examination of survivability and recovery of population, industry, and the economy presents numerous unknowns, but certainly indicates survival of and recovery from massive nuclear war to be realistic. The civil defense, hardening, and defensive measures for Soviet forces indicates they hold the view that nuclear war is survivable. Then, what is the possibility of continued hostilities and the role of other countries? What are the mix of weapons and forces left, the nature and capabilities of the surviving leadership, the degree of control over remaining forces, the available communications, intelligence and reconnaissance, and what is required to restore deterrence after nuclear weapons have once been used massively?

The limited use of nuclear weapons, the theater-war relationships and the Soviet recovery, civil defense, and counterforce capability argue that the MAD strategy is insufficient for deterrence. A broader perspective, which ensures the existence of a nuclear war-fighting capability vis-a-vis the USSR, may evolve as the determinant for strategic forces. This would provide a deterrence posture more consistent with views held by the USSR--and thus more likely to deter. The measures for strategic forces utility would shift. Correlation guidance for cruise missiles attacking a badly damaged nation would be examined. Even greater emphasis

would be given to survivability. New emphasis would be given to holding capability, reconstitutability, reload, retargeting, and reconnaissance. The old concept of an emasculated defense might be replaced with the possibilities for effective defense from space against ballistic missile attack.

There was some discussion of the technology emphasis such a shift in posture might engender. The capability for rapid reprogramming, relaunch, and replacement of space assets was noted to be of obvious importance. The availability of a hypersonic reconnaissance vehicle was noted as another possible need.

World of Nuclear Proliferation

Mr. Rowen drew upon his prior writings "Life in a Nuclear Crowd" to describe the likely spread of nuclear weapons. He noted that despite a good deal of rhetoric justifying national nuclear weapons programs, few of the countries with the capacity to make them have done so. Two developments now promise fundamental changes: one is growth in civilian nuclear programs and therefore an increased capacity to acquire nuclear weapons cheaply and rapidly; the other is a weakening of confidence in American guarantees of protection of allies.

By 1985 about 40 countries will have enough fissile material to make three bombs or more; almost as many are likely to have enough fissile material for 30 to 60 weapons or more. The Indian nuclear explosion of 1974 may have been the crucial "triggering" event between a linear growth in nuclear weapons acquisition, and an exponential future. The prospect that many countries will acquire weapons must be taken seriously, as must the short leadtime within which these weapons can be acquired.

Most analysis of nuclear stability is based upon a model of the US-USSR relationship, with exclusive concentration by the two great powers on deterring attack on each other's homelands. The possession of nuclear weapons by third countries is likely to bring about changes such as restraint by a large power in challenging what might be construed by the smaller as its vital interests. Between small powers, the relationships are likely to change with a race to acquire weapons first, and with support provided by the large countries in technology, in the reduction of forces vulnerability, in replacement of nuclear forces destroyed or in direct use of nuclear weapons against an

ally's adversary. The nuclear forces of small nations will be small, probably without reliable systems to warn of enemy attack, and perhaps weak in safeguards against unauthorized actions by those in the chain of command, and prone to accidents and mistakes. The large powers will possess many more resources for information gathering, offensive capabilities, command and control, civil defenses, antimissile and air defenses, etc. as well as the capacity to rapidly transfer technologies or information which could rapidly make opposing forces vulnerable or reduce the dangers of unauthorized use.

The countries most likely to acquire weapons are the nonaligned and marginally aligned countries, and those that feel threatened and fear abandonment. India, Pakistan, Iran, the Republic of Korea, Taiwan, Israel, South Africa, Argentina, and Brazil are some of nations with such rationales. Proliferation will increase the need for alliances among those countries threatened by rivals acquiring nuclear weapons. However, it is not clear that the great powers will be willing to make guarantees to countries with nuclear weapons on the grounds these weapons are no longer needed, nor to nations in a region with nuclear powers because it may be too dangerous. The potential for nuclear spread will have only been partially realized by 1985; many more potential entrants will remain during the following decade. Acquisition will likely depend upon the availability of materials and technologies, what happens to the countries that have acquired weapons, and the degree of security provided by alliance relationships.

US concerns, other than the instability that may follow from proliferation, are likely to be the intentional or unintentional use of nuclear weapons against US forces abroad, the use among third nations to which we may or may not be allied, the threat to US territory by another country or terrorists, and the accidental or unexplained incident. The US may find it necessary to increase its intelligence of third country nuclear activities, to allocate offensive forces to third country targets, to build up air, missile, and civil defenses to cope with these additional threats, to emphasize nuclear protection for forces abroad, and to develop a surgical strike capability for use against nuclear facilities or units. Specific technology relationships were not identified.

Mr. Rowen made clear that the main task is not just to forecast, but to try and influence the process toward nonproliferation. The discussion touched upon policies, practices, alliance relationships, and providing of nonnuclear

capabilities and cooperative international efforts to reduce terrorist possibilities. The prospects for control over materials and technical knowledge were considered by most to be too late and too little.

NATO War

Mr. Emanski drew attention to the characteristics expected of future land combat in Europe. He emphasized continuous combat because the Soviets have established it as their doctrine and equipped themselves to carry it off. Savkin's "Operational Art and Tactics" establishes the duration of the continuous offensive to be between 30 days and 8 weeks. The Soviet concept is to echelon forces so that the intensity of the offensive can be maintained at the points of combat contact along the main thrusts.

However, he noted that continuous combat would have evolved without a Soviet emphasis because it is a logical projection in the trends of warfare. Trends noted were: increased mechanization and mobility; technology that enables effective combat and movement at night; dispersion of forces required by the threat of mass destruction weapons; emphasis on force destruction and maneuver--learned in part from the German blitzkrieg--and the "ideal" toward which innovative combat commanders have been striving.

The dimensions of continuous combat are far-reaching, much more is necessary than simply emphasis on night operations. Fundamental changes in doctrine, organization, training and equipment are involved. The tempo of operations will increase as the present discontinuous or intermittent operating capability is replaced by sustained combat.

Psychological and human factors are a basic consideration. Rotation of forces is necessary. The time available for decisions will be reduced, requiring changes in present organizational and logistic planning, the organization of the forces to be used, and the conduct of the battle. Local intensities will require replacement and resupply well beyond current capabilities. Forces will be more highly mechanized with emphasis on numbers and mobility, in contrast with a few highly armored vehicles. Forward, highly mobile, tailored-to-the-situation kind of maintenance and overhaul will replace production-line, rear base concepts. A vital shortcoming may be the difficulties of transition from peacetime to wartime support. Day and night operation will

rapidly exhaust the high skill maintenance and operational personnel of air combat units. Dependence upon airbases for sustained operations and air supply while under attack by aircraft, missiles, and heliborne forces is a critical vulnerability.

Most of the technologies discussed during the colloquium match well the developments needed to attain a continuous warfare capability. Today the US has neither understanding of nor capability for continuous warfare. The consistent pattern in Soviet thinking and developments to date argues that the USSR will continue to exploit its technology to further its capability for continuous warfare.

Mr. Emanski observed that there are not three separate Soviet doctrines for chemical, nuclear, or conventional war. There is one. Soviet operational hardware includes protective garments, chemical warfare antidotes, automatic CBR alarms, sealed vehicles, a complete family of decontamination/washdown equipment, protected medical vans, a family of chemical smokes and aerosol generators, and so on. Nuclear and other weapons of mass destruction, chemical and biological, do not reduce the importance of continuous combat but rather underscore the reason this is likely to be the character of the next war. The point was brought out in discussions that while the US developed the neutron bomb, ostensively as a defensive weapon, it would be in fact a natural weapon for the Soviet style offensive since rapid movement into the target area is one of its desirable characteristics.

Two other characteristics for future warfare in Europe were identified by Mr. Emanski. First, it will be a coalition war and interoperability of doctrine, equipment, procedures, communications, and command and control is fundamental. A team wherein one-fifth of its members are playing one game while the other four-fifths play a separate game or games cannot expect to win. Second, military operations in built-up areas are unavoidable.

Mr. Greene added to the second point noting the continuing urbanization of Western Europe. This degree of urbanization will make obsolete NATO's long-standing strategy for forward defense using tactics designed for operations in open country. This is particularly evident in the North German Plain, which has historically provided the best east-to-west route for invading armies. Three urban complexes alone will cover 40 percent of the total NORTHAG-Second ATAF region by the

year 2000. These large areas could be an enormous liability to the defense of NATO, or they offer outstanding possibilities for improved defense if appropriate strategy, tactics, and equipments are developed and deployed.

Much discussion focused on these concepts for warfare in Europe. The perspective of Soviet developments leading toward a continuous warfare capability had clearly gone unrecognized by many. Also unrecognized was the extent of Soviet preparations for theater nuclear, biological, and chemical warfare made pointedly clear in the colloquium by Emanski, Greene and Augerson.

The result was a sobering appreciation of the situation likely to be faced in a European war. Mr. Emanski noted that the most significant benefit from recognition that continuous combat will be the nature of future battle would be the unifying purpose this could bring to all combat and material developments.

Information War

Dr. Rona stressed the conceptual aspects of countermeasures to make a number of points about the future of information disruption, manipulation, and misimprinting--information war. He noted the spectacular advances that have taken place in military technology--namely, propulsion, guidance, and warheads--so that whenever a weapon can be aimed at its assigned target it is highly likely the target will be destroyed. Protection in the past has depended on target hardening, target mobility, or timely counterattacks. Protection in the future will depend more and more on misinformation or information denial.

Jamming the command link of a surface-to-air missile is an obvious countermeasure. However, countermeasures can be applied throughout the development and use of a weapon system. Strategic intelligence is updated in bursts occurring in a matter of months or years; a carefully designed sequence of messages can cause reliance upon false input data and decision logic, for example a designer is vulnerable to wrong or deceptive signature data. Tactical intelligence, surveillance, or reconnaissance may deal with events measured in days and hours; the precious few and expensive weapons may be misallocated. Events related to the terminal engagement can take place in seconds or even microseconds; the precision weapon command link may be disrupted.

The future, as he saw it, will tend to reinforce new and sophisticated ways to apply countermeasures in their broadest sense; especially as technology opens possibilities for and vulnerabilities to transformation of about any physical phenomenon into electrical signals with the attendant capability for transmission, processing, and display. He added some predictions. The use of target-connected observables for high-accuracy terminal guidance of missiles will be avoided whenever possible. They are likely to be under the control of the enemy and therefore amenable to relatively inexpensive countermeasures. The trend will be away from high-value, concentrated, mobile platforms, to a number of relatively small, possibly unmanned platforms, synchronized by secure wideband data links. (The high asset concentration represented by the Trident weapon system must be seen as an anomaly in this respect.) The trend toward a large number of cooperative elements will permit design of small but significant individual differences thereby providing multiple-complexions for the enemy to face. Space-borne surveillance will reduce or eliminate depending upon emissions direction-finding and thereby shift the emphasis from silence (e.g. by ocean vehicle) to one of open broadcast where the emphasis is upon achievement of confusion and disinformation. The trend will be toward one-time-use systems such as an unmanned precursor penetrator to deploy local beacons for temporary target attack. C-Cubed systems will be adaptable to rapidly changing combat environments, including the confusion messages deliberately provided by the enemy days, weeks, months, or even years before the actual start of overt hostilities. Finally, equipment for training people to handle various aspects of information war will be important, in particular for the training of military people with different cultural backgrounds.

During discussion Dr. Rona suggested two changes that would be an important response to these futures. First is the imperative need to address the information war-related moves throughout the whole evaluation and operational life of newly proposed or upgraded weapon systems. By contrast, attention to countermeasures is now an afterthought frequently lost in budget cuts. Second, a C-Cubed/intelligence simulation laboratory is needed to explicitly focus on the stressed behavior of complex combinations of high-performance links and human interface under conditions of an unintentionally or intentionally distorted reference base. This laboratory could aid training as well.

Small Unit Operations

Nonintervention as a defined or undefined national policy is perhaps a rationale for inattention to small combat units. Yet hazardous politico-military operations such as "surgical strikes" in support of antinuclear proliferation or assurance of energy supplies, the rescue of hostages from terrorist groups, and selective antiguerrilla operations are anticipated by many as likely low-level conflict needs for small units over the next two decades. Wartime raids against critical high-value behind-the-lines targets form yet another role for specialized small unit operations. General Henderson acknowledged these roles, but presented a broader view of small tactical units applicable at all conflict intensity levels and in all geographic environments.

He argued that the expanded combat capabilities which technology could give the small tactical unit would change and dictate the nature of ground combat in scenarios foreseen and unforeseen. He noted the area controlled by a large force (approximately 100,000 men) increased by five between the Civil War and World War I, by 12 between World War I and World War II, and by 10 since World War II. He said another gain of this magnitude is possible by the end of this century, that is, 30 to 50 man units could control a four-square-mile area against the Warsaw Pact or nearly the equivalent of today's infantry battalion. But this benefit cannot be realized if we merely applique modern technology in a random fashion to present day small combat units and their operating concepts--the small unit must be developed as a truly integrated combat system in a manner analagous to that for a new tactical aircraft.

The small unit can have a terminal in global and local positioning systems to locate and to direct supporting fire. It can have the capability to transmit voice, digital and video to support units. Automatic attention and output interpretation from line-of-sight and non-line-of-sight sensors can eliminate constant operator attention while providing detection and identification of physical objects and emitters. Deception and decoy devices can be available for those most likely to be detected and attacked by an advanced technology enemy force. Organic multipurpose precision weapons utilizing nuclear, electromagnetic pulse (EMP), nonlethal CW and conventional munitions can be carried for use against ground and air vehicles, structures, area targets,

and electromagnetic emitters. Development of the combat unit as a system is the key to realization of these capabilities for large force conventional or nuclear conflict. It is also the key to the versatility and effectiveness of modified units for independent operations. The infyonics concept, so labeled by General Henderson, prompted exciting discussion. Many readily appreciated the significance of small units if the promised gains of new technologies were to be realized in large force operations. They also appreciated the ready spillover of this focus for development of small, independent teams. However, there was much doubt that even recognition of these possibilities could overcome the old habits of emphasizing the hardware.

Food/Water Crisis

Dr. Doty cited the production and distribution of food as a potential security concern. Vulnerability exists because of the increased dependence on a relatively few species which for the most part do not have high resilience to unusual infections or unusual variations in growing conditions. The development and nurturing of new genetic species and the storage of seed stores are logical defenses. He foresees these, and vigilance against destructive acts, as elements of national security in the 1990s.

Dr. Anderson drew attention to water as an essential natural resource. Historically, the demands on water have increased and will likely continue to do so. Economic growth has not only stressed water supplies but, coupled with land-use practices, water quality as well. We lack understanding and modeling capabilities of water quality and its attendant geochemical, biological, and hydrologic controls, particularly regarding persistent toxic substances. The issues of food and energy will invariably stress the resources further. Whether climatic shifts will occur, ameliorating or aggravating the imbalances of supply and demand is uncertain.

National security has not been defined as an objective of water planning. Had chance not conspired to end the 1930s drought before the nation entered World War II, the consequences would have been harsher. He concluded by noting that the resource systems evolved during the quiescent periods may well lack the resilience to respond to the demands that might be imposed upon them during periods of national stress.

Energy-Related Scenarios

The technologies of energy were not addressed in the colloquium, except for the charged particle beam, electromagnetic gun, and some vehicle propulsion ideas. Energy as a source of conflict was to have been included in the colloquium, however, the speaker who was to have discussed this topic was unable to attend. A few of the points that would have been addressed are included here in order to add to the forecast considerations.

Increased world dependence upon oil through the rest of this century is accepted even among those with optimistic predictions for coal, nuclear, and solar power applications. This creates a number of potential security problems. The United States itself depends directly on sources in the Middle East. Military contingencies must protect these sources and their supply lines from acts by the Soviets, by hostile Middle Eastern nations, and by terrorist groups.

Our major allies, Western Europe and Japan, are more dependent on these sources and lines than is the US. Thus protection of these sources and supply lines is essential to their economies in peacetime and critical to their existence and the conduct of defensive military operations in wartime. Concern over continuous theater war seldom addresses this vital supply question. However, far short of war, the more critical dependence of these nations upon outside sources is likely to bring about differences with the US which may alter alliances during these next two decades.

The Soviet Union now exports oil to Eastern and Western Europe. Many estimate that it will be unable to increase its production sufficiently beyond the early 1980s to maintain this favorable position. A further pinch in their economy may result, as noted in the remarks by Mr. Earle. Reduced supplies to East Europe may in turn cause these nations to depend more upon Middle East sources and to seek more Western hard currency to buy Middle East oil. If the Soviet Union's shortfall were severe enough, it could become an importer of oil and thus an active competitor for Middle East oil sources.

Japan, the People's Republic of China, Taiwan and Korea are potential competitors or collaborators in the development of oil in the East China Sea. The less developed nations (LDC) in their attempts to industrialize have no choice but to depend upon oil and thus to compete with the industrialized nations for the available supplies. Frustration and instability are certainly likely.

Overall, two points were to have been made by introduction of this topic into the colloquium: first, that energy supplies, particularly oil, are unquestionably a source of tension and possible conflict during the next two decades; second, that access to these supplies may even more importantly become the cause for change in current alliances and the creation of formal or informal alliances between nations now presumed to be neutral or joined in common interests with the US or the USSR.

RESOURCES & UNCERTAINTIES - USSR

The Soviets' military competition was identified as serious. Examples of good Soviet design, and of their impressive match of doctrine and equipment were given throughout the colloquium. Their nuclear-biological-chemical capabilities drew special attention.

Dr. Stevens pointed out the inexorable commitment of the Soviets to expenditures in defense and to maintenance of a technological capability different than our program-by-program approach. He noted on the other hand the inertia of their system and the difficulties which they admit to themselves are likely to hinder their application of high technology. The forecast these may present was debated but certainly not resolved during the colloquium.

Past analysis has innately assumed the Soviets to be a mirror image of ourselves. Dr. Stevens noted our knowledge of the Soviets, as illustrated during these discussions, now is far greater than during the past decades. Consequently, we can in fact be more selective in what we choose to pursue to gain advantage for our forces.

Soviet Resources

Mr. Earle presented an overview of the generally accepted estimate of decline in the Soviet economy; a decline in annual growth from 4.5 percent currently to a 3 percent during the later part of this century. This estimate is based upon limitations in the work force, insufficient energy production, along with the Soviets' normal problems with agriculture. European perceptions are less negative and tend to project growth of the economy at current rates. The Europeans do not foresee the energy problems for the USSR to be as severe as seen by US estimators.

The Soviet leadership does see problems ahead and does appear to recognize that this means allocation difficulties. However, it has not developed an economic strategy yet. The next five-year plan, expected in 1980, might give insights to the choices. But he thought it unlikely and suggested the Soviets would probably wait out the period and make changes in the subsequent plan.

Foreign technology is a source of improvement for the Soviet economy. Thus far the Soviets have concentrated on achieving bulk additions to their capacity. Difficulties in absorption continue, but clear gains have been made.

Beyond the question of how much gain, the basic question is whether the USSR will make a long-term commitment to be part of the world economy, or whether it will once again withdraw into isolation. The exports it has developed have paradoxically been products of high internal demand (autos for example). However, this may be an example of conservative planning in that should the products fail in the export market they can readily convert to fill domestic needs.

Projections of economic growth lead to projections of defense expenditures. US estimators have previously disagreed with the low numbers held by the CIA. The higher CIA numbers now do not resolve the questions, as the shape of the expenditures curve still does not reflect force deployments. It is one thing to say what a number is not, it is quite another thing to say what it is.

A decline in the rate of growth of Soviet defense expenditures is projected. But the actual expenditures are significant, and Mr. Earle estimated long-term growth of defense expenditures at 4 to 6 percent annually; that is growth faster than their overall economy. The military sector is also expected to become more productive. He cautioned that we should not look at the Soviet economy in our terms. A stable economy, even if sluggish, is desirable for the USSR. Opportunity costs are not viewed with the disdain they are in the West, and thus the "burden" of military expenditures is less troublesome. In comparative terms, as the Soviets view the current turmoil and problems of the Western economies they can live with their own problems more comfortably.

Soviet R&D Patterns

The basic point made by Earle and Alexander was that in comparing the US and USSR, we must think more in terms of Soviet process. Dr. Alexander noted that evaluations of US and Soviet military R&D often begin and unfortunately end with inputs (budgets, engineers, educational levels, and so on). However, given a gross comparability of inputs, it is in the process and choice that sharp differences emerge between US and Soviet practice.

Dr. Rechtin gave examples from his experience with the DOD where repeated assumptions were made that the Soviets would use their comparable, or enormous, R&D investment to close military technological gaps. Instead they apparently have not seen our leads as that important for they have used their resources quite differently than we.

Yet have we been surprised? Many argued that we really have not been surprised, in great part because we have been able to observe and obtain data from their testing. We have not been surprised by the operational effectiveness of their weapons; but we have indeed been surprised by how they achieved it--that is by their designs.

Dr. Alexander identified recognized features for the bulk of Soviet military acquisitions as simplicity in equipment; common use of subsystems, components and parts; incremental growth; and limited performance and mission capabilities. This pattern has been pervasive in the past and is likely to be so into the future. We have now acquired a fundamental understanding and data that can enable us to make sounder judgments of future Soviet capabilities--and thus to be able to be more selective in our response.

Exceptions have occurred. These exceptions with their own recognized pattern have included nuclear weapons and long-range ballistic missiles. Directed energy beams may be an example of an exception today.

Dr. Alexander described in his presentation the Soviet process of weapons design. He made several points; principal among these was that while their weapons technology is on the whole less advanced than ours, there is considerable evidence that these technological lags often do not result in lessor military value.

He noted the common answer to this seeming paradox to be that the Soviets compensate for technological inferiority by fielding masses of men and equipment, and by spending more on its military might than potential adversaries. He showed this answer to be only partial. In many cases, Soviet weapons on a face-to-face basis are indeed comparable to their Western rivals. One comparison of jet engines with similar performance showed the Soviet engine to have only one-tenth the parts, one-third the cost, and larger manufacturing clearances. While the latter resulted in test-stand degradation, the engine did not degrade in operations as did US engines.

He suggested the additional reasons for Soviet weapon effectiveness lie in the continuity of design teams and the continuous construction and test of prototypes; in the extensive troop testing of new equipment within large-scale exercises, which they do as part of the acquisition process; and in the criteria which they use to evaluate weapons, that is they use force utility as the measure, not one-on-one weapon performance.

Skolnik on radar, Bement on materials, Gray on the AK-47 and others gave examples of good Soviet design, adding emphasis to the point that we are false to ourselves if we continue to call Soviet technology inferior. Discussion moved back and forth from engineering respect for the design achievements of the Soviets to concern lest the image conveyed of the Soviets is that of "doing all the right things." The latter is clearly not true. Equally true is that the technological lags normally attributed to the Soviets need represent neither lag in military value nor lag in engineering sophistication. Mr. Kahn summarized for all by saying that the Soviets do incredibly well within their limitations, and we could learn some things from them--some features of Soviet acquisition practices could be beneficially applied here.

RESOURCES & UNCERTAINTIES - US

Concern was expressed throughout the colloquium that the threat and problems not be overstated--but be credible. The United States possesses fundamental economic, technological, industrial, and military strengths. More generally, the industrially more advanced Western nations (NATO) have a population of 560 million in contrast to the Warsaw Pact population of 365 million and have a combined GNP over twice as large as that of the Warsaw Pact. Clearly, adequate resources are available.

Clear as well is that we in the United States have much technology across all fields. The state of the art is high. The presentations and discussions covered an impressive array of our technological capabilities. Priorities likely to maximize the leverage for the United States were suggested for DOD technical resources.

Dr. Davis said the colloquium showed the military systems to be beneficiaries of many technological options, and not the captive of shortfalls. The presentations in 26 areas of technology provided reasonable comfort that desired competition in technology will occur and is adequate for intelligent selection of a few system efforts with a high probability of operational success.

She emphasized that continued competition within the US in technology is inexpensive; and should be proportional to potential payoff, scientific uncertainties, and the quantity of systems/components planned for procurement. Demanding a winner before beginning R&D encourages a stifling conservatism in contrast to a stimulating innovativeness.

The unsatisfactory capability to place and use our technology in the field was not an agenda topic. Our dependence upon technology to equalize the Soviets numerical advantage, as identified in the keynote remarks, brought the topic to the fore. The contrast of the attractiveness of future technological possibilities, with examples of our failures to exploit today's technology, was natural cause to project that these future possibilities might not come about.

Technology As An Equalizer

Dr. Davis cited some group opinions that had evolved. She noted that in the view of many we have fewer problems generating new technology than in translating that technology into fielded equipment. Dr. Lukasik noted that the time between technology "generations" in a number of important areas cited as less than the DOD procurement cycle. The DOD acquisition process was seen to unwittingly degrade our technological advantage and thereby equalize the US and Soviet military prowess. We wish to meet the threat by using high technology; and thus we must be concerned by impediments.

Dr. Berenson echoed the keynote charge--the key question is what technological initiatives should the US take in the near term to make the maximum increase in relative total deployed military capabilities in the next 10 to 20 years. An important part of this problem is the fact that the Soviets are outproducing us in most major weapons systems which means they can modernize their forces faster even though they may start out with a technological disadvantage. We need to develop ways to decrease the time from the availability of technology to full operational capability of the system. Dr. Berenson emphasized that production, training and maintenance technologies are important in addition to the weapons system level of technology.

None doubted the fundamental technological strength of the United States or in a larger context that of the West as a whole. The USSR's "worship" of science, coupled with their respect for Western technology adds to our basic strength. Recognition of the seriousness and character of past and current failings, and corrective actions, were seen to be critical to the national security and to realization of the benefits from our technological strength.

The colloquium discussions offered insights both for significance of technologies and therefore selection. Insights for more rapid assimilation of technology are recorded in this section. The point made vividly by several operational personnel was that our technological superiority is not obvious to the man in the field. We cannot gain the leverage we desire from our technology by selection alone, we must focus on its assimilation into military operations.

Numbers Are Important

This message was one that most participants put forward. No one doubted the need to use the US technological advantage to overcome the numerical advantage of the Soviets today--and in the future. The fear was that technological superiority or quality versus quantity has been for too long a cliche preventing necessary investment in mass. Extracts from a 1976 speech by Senator Sam Nunn of Georgia expressed this point for most:

--At some point numbers do count.

--At some point technology fails to offset mass.

--At some point Kipling's "thin red line of heroes" gives way.

The approximately 3 to 1 ratio of procurement to research and development was cited as clearly disbalanced--with note that industry figures are more like 10 to 1. Some concluded the technology investment was about right and the procurement should therefore be increased. Others said the need for numbers was serious enough to warrant sacrifice from the R&D budget so equipments could be procured for the field. This emphasis does not mean to buy ships to counter ships, tanks to counter tanks, and aircraft to counter aircraft--although that is indeed part of the answer. Clearly it also means a skeptical examination of the purported claims for one-on-one performance, where the alternative is more of a cheaper version, and it also means emphasis upon surveillance and command-communications where these can affect appropriate massing or avoidance of disadvantageous combat.

A more fundamental point was made regarding numbers and the exploitation of technology. The lack of large procurement, and thus numbers deployed to the field, means that our military forces are not able to gain experience in the use of these equipments. The research and development community can hypothesize the use of these equipments, but they really do not know.

US hardware and software R&D has outrun what may be termed operational R&D--or learning what it is good for. Furthermore, we know that equipment by itself is not the answer, but rather the combination of the right tactics and the equipment as used by men. The development of tactics, or assimilation of the technology, depends upon the existence and use of numbers.

Ability To Execute

Criticism of unreliable and/or unsupportable deployed equipment recurred throughout the colloquium. Examples were given of field personnel unable to keep equipment in commission. A failure ascribed to design, to training and to inadequate spares. Consequently, operational units have no confidence in their equipment and, because it is not in commission, they are unable to train. The fact that this is an old complaint should make it even more deserving of attention.

New technology and new equipment carries for the operational commander the image of more headaches. The promise of higher reliability of integrated circuits, the ease of operation and maintenance by use of processors, the low maintenance promises of materials developments, etc. must overcome this hostility. Reliability-maintainability programs remain ever present, but never up to the task.

Those present put forward three interrelated answers for this old problem. First, the new technologies do offer real opportunity to reduce reliability-maintainability difficulties of the past. Second, major design emphasis must demand reliability-maintainability and stick to it. And third, both money and time for reliability, maintainability, and producability in design must be explicitly provided and treated as sacred within the acquisition cycle for future equipments. Normally, these are secondary to weapons performance features and eventually are pushed to the side to gain an early operational date or budget savings. Reliability and maintainability of equipment is a means, not an end itself; the end as General Gray stated is the survivability, efficiency, and ability to execute of the soldier, sailor or airman.

Design For Mobilization

Mr. Kahn drew upon history to make a major point. The debates of June 1950 were whether the United States could afford a $14 to $18 billion defense budget. The Korean War began and Congress authorized $60 billion. The consequence was that we were able to afford such systems as the B-47, B-52 and Minuteman, none of which singularly would have been affordable under the expected service allocation of $5 billion annually. Our military superiority sprang from this jump.

Nobody in 1950 studied big budgets, all thought within $5 billion annually. The precedent of a sudden jump in defense spending should not be ignored--the Soviets certainly fear our mobilization. A sufficient scare could cause us to commit a trillion dollars to defense; we should now spend $1 to $2 billion per year to prepare for this event. He argued that our highest priority should be to look upon, and design, our forces today as a minimal force--a basis for expansion.

This priority would mean investment in long lead items. More importantly it would mean experimentation and design with a view to rapid expansion of our capabilities. That very well could mean deemphasizing from "ultimate" designs in favor of simpler designs, and deemphasizing from one-for-one replacement of ships, tanks and aircraft in favor of the command and support systems. Other answers exist--Mr. Kahn's point was that the capability for force expansion not only is historically sound, but would generate desired design directions.

Operations R&D

Dr. Lukasik described one of the more important suggestions put forward for change in the acquisition processes as "operations R&D." The concept is to achieve evolution through operational exercises and use; and while obviously not applicable across-the-board, it could be instrumental in the development of many new uses, new doctrine, and the actual assimilation of new technology.

This change was suggested to address what many saw as a major failing of the acquisition system. That is, the presumption that each system is forever, and therefore its characteristics must embody all future requirements--and axiomatically all the latest technologies at its IOC.

The technologies of the future lend themselves to incremental update of systems. The conflicts of the future are likely to require adaptation. A point, already noted, was that while the research and development community can hypothesize the use, it really can not know. These, most participants argued, are cause for explicit emphasis within acquisition for field evaluation and experimentation with many new equipments in order to learn of their use and to feed back design changes. Innovation and rapid assimilation of technology were seen as the gains; but time and money needs to be explicitly provided within the acquisition cycle in order to achieve these gains.

Two points were then made with respect to technology as an equalizer. First, that the United States should possess great advantage for leverage from the processing explosion in contrast with the USSR. But second, that this potential is unlikely to be realized unless we can focus on experimentation and evolution along the lines brought out throughout the discussions: infyonics, distributed systems, life sciences, naval surveillance, microprocessors, and so on.

Adm. Martell suggested further gains. He agreed with the view of many that the most likely events of the next decades were those of crisis, incidents, and challenges. He related future responses to new challenges, in possibly new geographical areas, to Mr. Kahn's point about emphasis upon experimentation and designs for rapid expansion of capabilities. He gave an admittedly parochial example: the need not to buy for the fleet, but to experiment with droppable sonar buoys which could be read out by satellites.

His fundamental point was that normal budget activities, which focus on platforms, on mission definitions, and on life-cycle costs, leave no room for such small quantity experimentation and learning. These procedures force a "commitment" to buy and deploy--after a cost-effectiveness comparison with other future buys--even before the experimentation takes place. Cheap learning, and possibilities for expansion to meet new contingencies, are thereby forgone. Rather, money, labs, test organizations, firms and operational units must be pulled together and given the opportunity, or even the explicit assignment, to undertake the test for operational possibilities and problems before commitment.

Innovation In US

The incentives and disincentives for innovation in the US were the topic of an evening session at which Mr. Oliver Boileau, President of Boeing Aerospace Company, and Dr. Robert Noyce, Charman of INTEL, spoke. However, discussion was not limited to this session, as the contrast between the technically possible and the deployed prevailed throughout the colloquium. Both a strong sense of frustration and some suggestions for new directions were recorded. The topic is particularly apt, since a long list of the technical possibilities cannot comprise a forecast; but rather these possibilities must be overlayed with trends that will bring forward or constrain them.

Mr. Boileau cited the fundamental advantages this country has in its industrial and technological base. He then addressed the inability to move technology into inventory from a defense contractor's viewpoint. He identified the government as the greatest inhibitor today, both the regulations and the management processes. The latter is best illustrated by the question of who is the customer: the Service program office and boards, the DSARC, the Defense Secretary, OMB, the President or the Congress. These comprise a hydraheaded buyer, any mouth of which can say no before a system can be put into production long enough to make money for the firm.

He addressed a common misunderstanding. Government funding of developmental work does not cover all costs. If you are innovating, industry must dip into its own resources. BAC invested $50 million of its funds in the recently canceled Advanced Medium STOL Transport (AMST); but increasing losses from cancellations make it tougher to justify future investments. Boileau's point was not to create a taboo against program cancellation; but rather that this intolerable lack of common purpose and apparent national will to maintain a strong defense undermines innovation.

Innovation funding, or the problems associated with obtaining these, recurred throughout discussions. Mr. Boileau contrasted the commercial marketplace incentives with those of defense. The former have been substantial enough in the past for Boeing to periodically risk its entire net worth to bring out the next-generation product. He noted that in current dollars, Boeing put 1.7 billion into the 747. The point is real even though the contrast of defense and commercial incentives may not be as drastic. BAC does invest heavily in IR&D for defense; and a recent Fortune article noted the potential sizable Northrop commitment but not its entire worth to the F-18. Funds for commercial innovation are not readily available either, as Dr. Noyce made clear, citing the trend over the past five years. This problem stemmed from tax disincentives, from available money going into short-term returns, and from investment houses unwilling to put money behind technology without assurance of Xerox-like performance.

Others maintained that cautious attitude within government laboratories inhibiting both innovation activities in the laboratories or the funding of innovation outside. Freedom to expend at least limited sums and manpower without defendable mission results or assurances of success has disappeared. This was seen in part to be the lack of

"great directors," but likely more attributable to the hyperactivity of budget and "exposure-minded" reviewers and media. Lastly, note was made of the difficulties for universities to obtain research funding. The expenditure of time and money to obtain a research dollar have become excessive to the point where they inhibit active research.

Dr. Noyce made a strong pitch for increased government funding of university research--but with greatly reduced red tape. He argued that this is where the future innovative industries, such as that of semiconductors, must begin. By contrast, research within private firms is inadequate, their research is not shared, nor is it directed at other than short-term interests, e.g. defensive in nature. Furthermore, the technologists trained through research in the universities are the source of our innovative manpower.

Different viewpoints were given on the problem of government regulations and procurement practices. Mr. Dale Church (Deputy Under Secretary of Defense R&E for Acquisition Policy) described the effort under way to rewrite the procurement regulations, the ASPRs. Simplification and incentives for industrial motivation, including profits, are sought through these changes rather than relying on regulations. Several discussants expressed caution over the expectation that changed instructions, by themselves, would have much effect without extensive re-education for all throughout the government involved in the administration of procurement.

Dr. Rechtin pointed out that much government regulation has come about because some in industry lobbied for the regulation and cited a number of examples. He pointed out that if less constriction is to come about, an industrywide willingness to operate in a more competitive environment will be necessary.

Mr. Boileau's example of the AMST cancellation brought out another point. The Soviets announced their intention to produce their smaller version of the AMST about the time the US announced cancellation. It apparently uses the upper-surface blowing technique developed by Boeing, it has the same engine placement, landing gear, and so on. Thus the Soviets are gaining experience with our innovation, while our knowledge rests in file drawers.

Dr. Alexander separately noted one of the reasons for Soviet weapon effectiveness lies in the extensive field testing of new equipments within large-scale exercises as

part of the acquisition process--that is, the explicit determination of the military utility of the equipment and its features. Many expressed the belief that the US could accelerate the choice of and assimilation of new technology for military equipment if similar emphasis were given to operational unit evaluation and experimentation. US unwillingness to explicitly provide funds and scheduled time for such experimentation was seen as a major impediment to both useful innovation and effective assimilation of new technology.

The 10-year acquisition cycle was repeatedly cited as outrageous because it means much of the technology embodied is at least a decade old by the time it's deployed, because it means stretch-out costs are unavoidable, and because a malaise sets upon those in the technical and systems fields. Dr. Noyce noted that in the commercial market you do not tell the customer about your future line, or you will not be able to sell your current line. Many thought this version of "the best is the enemy of the good" explained much of the long acquisition cycle. Military requirements were seen to be less real than a statement of future technical promises. Designer-managers of military systems were seen to de-emphasize design simplicity and thus unable to reject attempts to incorporate all advanced elements at once. Suggestions included the clear demarkation of technology efforts from those of systems development, more competitive and shorter-term systems development, and explicit use of field experimentation with new technology where the military utility needs to be shown.

Mr. Boileau returned several times to the point that when a need is seen to be serious someone steps forward and quickly separates the vital from the unimportant, the critical from the unessential, priorities are set, and red tape is cut. He and others cited examples drawn from wartime, a national purpose--such as putting a man on the moon--or a "skunkworks" type operation. However, the point many made is that the problem is not how to exploit technology for one project, but how to exploit technology across the spectrum of military activities. Industrial approaches were suggested, but caution was advised as to which experience should be drawn upon. General Henderson suggested that AT&T, not the Soviets nor the aerospace nor the automakers, might be a good model for the DOD to examine as applicable to its across-the-board activities.

Mr. Kahn outlined his view that economic growth could slow down, or even stop, not because of resource scarcities, pollution problems, nor complex organizational difficulties but solely because of indifference or even hostility to economic growth and advanced technology--a cultural change. Understanding the direction of cultural changes requires a grasp not only of how people conduct their everyday lives, but also of the aspirations and visions of various influential groups. As these visions are shared by more and more people then personal, public, social, and economic policies are altered to conform to these new directions. He cited 12 "new" emphases and trends in the US that are becoming increasingly influential and threatening economic growth: avoiding the risk of doing something positive by innovation because it cannot be evaluated and the development of general antitechnology, antieconomic attitudes were two of the more obviously appropriate to the discussion.

Mr. Boileau noted, that the media, playing to these attitudes, are responsible, directly or indirectly, for much of the delay in getting technological innovation into the field. They spread inordinate caution among the decision-makers--what Arthur Kantrowitz calls a period of "timidity's triumphs." He saw the growing disbalance in US-USSR strength as sufficient cause for immediate attention. Waiting for a crisis to suddenly change these cautionary attitudes and then saying "go" to technology exploitation is not the answer. Suggestions included a major national effort to cut away government-created disincentives; an honest comparison between the Warsaw Pact and NATO forces and the inevitable consequences of the Soviet ICBMs; and an honest campaign to demonstrate the positive gains of American know-how and entrepreneurial ability to advance the economic good and stability of the world.

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Approved For Release 2004/09/03 : CIA-RDP86B00269R001400080001-7